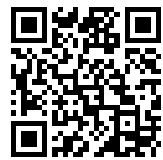
This is a reproduction of a library book that was digitized by Google as part of an ongoing effort to preserve the information in books and make it universally accessible.

Google™ books

https://books.google.com



Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google

432

TRANSACTIONS

OF THE

GEOLOGICAL SOCIETY

OF GLASGOW

VOL. XIII.

1905-1909.

GLASGOW: PUBLISHED BY THE SOCIETY,
AT ITS ROOMS, 207 BATH STREET.
1909.

Digitized by Google

The Editors beg to state that the Authors are alone responsible for the facts and opinions contained in their respective papers.

PETER MACNAIR, F.R.S.E., F.G.S.
FREDERICK MORT, M.A., B.Sc., F.G.S.

Digitized by Google

LIST OF ILLUSTRATIONS—VOLUME XIII., PART III.

			PAGE
Plate	XVI.	Micro-photographs of Rocks from the Ballantrae District, - - - - - - - - -	*to face* 288
,,	XVII.	Micro-photographs of Discs of Gypsum from "Eyed" Coal, - - - - - - - -	,, 292
,,	XVIII.	"Eyed" Coal from Gateside Colliery, Cambuslang, - - - - - - - - - -	,, 294
,,	XIX.	Micro-photographs of Post-Carboniferous Intrusive Igneous Rocks of the West of Scotland, - - - - - - - - -	,, 316
,,	XX.	Fig. 1. The Whangie, from the North. Fig. 2. Necks near the Whangie, looking North, -	,, 336
,,	XXI.	Micro-photographs of Rocks from the Auchineden District, Kilpatrick Hills, - - -	,, 342
,,	XXII.	Fig. 1. Micro-photograph of Ballochmyle Red Sandstone. Fig. 2. Polished Slab of Ballochmyle Red Sandstone, - - -	,, 360
,,	XXIII.	Micro-photographs of New Red Sandstones of the South and West of Scotland, - -	,, 364

FIGURES IN THE TEXT.

Vertical Section of Strata associated with "Eyed" Coal, - - 292

Diagrammatic Section across Auchineden District, - - - - 325

Sketch Map of Burn Crooks, - - - - - - - - - - 326

Longitudinal Section of Puddle Trench, - - - - - - - 327

Sketch Plan of Auchineden District, - - - - - - - - 331

Figures illustrating forces on Prisms subjected to Crushing, - - 369

570616

Digitized by Google

Digitized by Google

TRANSACTIONS

OF THE

GEOLOGICAL SOCIETY OF GLASGOW.

No. I.—Note on a Specimen of "Glyptoscorpius" from the Coal Measures of Airdrie, the Property of Robert Dunlop, of Baillieston. By Dr. B. N. Peach, F.R.S., F.G.S., *President.*

[Read 10th February, 1887.]

The specimen exhibits a dorsal view of about one-third of the carapace and portion of seven dorsal and two ventral sclerites of the trunk (abdomen) of an arachnid covered with a minute sculpturing, hitherto considered characteristic of the eurypterida. The carapace has evidently been divided into lobes by a central depression, the posterior portion of which is preserved. It is along this groove that the central eyes should occur, but, unfortunately, that portion of the carapace is not preserved. Towards the right anterior broken margin of the carapace, and at a lower level in the shaly matrix, a chelate limb is seen. This probably represents one of the smaller nippers or cheliceræ of the scorpions and phalangids, for it is more than likely that the large nippers of the scorpion were represented in *Glyptoscorpius* by an antenna-like limb, such as that now found in the phalangids, with which recent group these older animals appear to be allied. The recent "harvestmen" still retain a sculpturing on the harder portions of their test almost identical with that to be found on the present specimen.

One of the chief points of interest about the specimen is that it occurs in a higher horizon than any from which

Digitized by Google

glyptoscorpius (eurypterus) has hitherto been recorded. Taken in conjunction with the fact that Mr. Bennie has been finding fragments of the test of glyptoscorpius from almost every coal seam and "dirt bed" representing carboniferous land surfaces,

Glyptoscorpius minutisculptus.

the occurrence of this specimen in the coal measure shales, and embedded along with plant remains, goes far to confirm the conjecture that glyptoscorpius was a land animal and an air breather. Probably for this very reason it has hitherto been

Digitized by Google

very difficult to obtain anything but broken fragments even of single plates of such animals. It is to be hoped that, now the attention of geologists is directed to the occurrence of these interesting land animals intermediate between eurypterids and some of our recent spiders, more perfect specimens will be secured, by means of which their structure and true affinities may be more fully demonstrated.

Should it be thought that a specific name were desirable, I would suggest that of *Minutisculptus*, from the minute character of the ornamentation by which every portion of the animal seems to have been covered.

Digitized by Google

No. II.—Notes on the Geology of Glasgow's Highland Park. By James Stark.

[Read 12th October, 1905.]

The peninsula between Loch Long and Loch Goil, hitherto known as "Argyll's Bowling Green," should be of special interest to local geologists, inasmuch as, thanks to Mr. Cameron Corbett, it is now Glasgow's bowling green, a name resembling that of a street in Damascus reputed by tradition to be "the street which is called Straight," but which, according to an American traveller, while not quite so straight as a rainbow, is considerably straighter than a corkscrew.

Our new possession is somewhat less than 6 miles in length, and somewhat more than 2 miles in average width; it consists of a mountain ridge 2500 feet high at its northern and 1500 feet at its southern limit; the gradient of its slopes is seldom less than 1 in 2, and not infrequently its flanks are precipitous.

The southern portion of the peninsula is composed of that zone of arenaceous schists known as the Ben Ledi grits, which give rise to the peculiarly rugged scenery of the Trossachs region. In the more northern parts the softer micaceous phyllites of the series are also in evidence.

The foliation of the grits appears to be in this district more or less coincident with the original sedimentary bedding planes of the rock, and, along the shores of Loch Long, dips at a high angle towards the south-east. When followed up Loch Goil the angle of dip is seen gradually to lessen, until the folding becomes nearly horizontal, undulating gently, and dipping sometimes towards the north-west, thus presenting the appearance, at least, of the limb of a great anticline, but, as to whether it really is so, doctors differ, and deponent sayeth not.

There can hardly be a better locality than this for the study of the foliation of these ancient sediments, as the massive grits have been folded, rolled, and sheared again and again, under enormous lateral pressure, set up by the slow secular cooling and contraction of the primeval earth. It is very difficult to realise how such materials could have been actually made to flow into the most minute curves and wrinkles. This process must have taken place with exceeding slowness, and under the

Digitized by Google

superincumbent weight of vast piles of material now removed by denudation. Had it been otherwise the rocks would have been simply crushed to fragments, whereas the very pebbles of quartz and felspar which occur in some of the grits are seen to be stretched and drawn out into lenticles, as if composed of some ductile material like lead.

The mechanical energy thus expended must have developed a very large amount of heat, but, if the process was slow, the heat would have had time to be conducted to the surface without giving rise to any very high temperatures; on the other hand, however, there must have existed a more permanent high temperature, due to the depth beneath the then surface at which the present rocks were folded, and it is certain that the solvent action of water, or of H_2O, at a high, though probably not a very extreme temperature, has had much to do with the metamorphosed and mineralised condition of these rocks.

On the Loch Long shore, and within a quarter of a mile from the southern point of the peninsula, there occur a number of faults and crushes, running almost due east and west, and crossing the north-easterly strike of the foliation at an angle of about 40 degrees. In some cases these appear to be mere crushes, in which no movement has ever taken place; but in other cases, the same fissure varies in width from a few inches to some feet, showing that at least horizontal movement has taken place, and that these are true faults. These fault fissures are filled with a crush breccia of fragments of the schists, cemented together by calcite, which has generally weathered out, leaving the walls of the fissures exposed to a depth, in some cases, of several feet. Fragments of the schists projecting from the calcite are also seen to be much weathered, but this has taken place only on exposure through the more rapid weathering of the calcite. A fractured surface shows that, where still embedded in the calcite matrix, the schist fragments are perfectly fresh, indicating that the infiltration of the water from which the calcite was precipitated took place far beneath the surface, and out of the reach of the weathering agencies.

In some cases, the calcite filling still adheres firmly to the walls of the fissures, but in others it appears to have been disturbed by later movements, allowing acidulated water to find

Digitized by Google

its way in and dissolve the calcite, so leaving an open space some inches wide between the filling and the walls of the fissure. Some of these faults may be seen on the Loch Goil shore, although, owing to vegetation and rock débris, they cannot well be traced across the intervening hill. At least one similar fault may also be seen on the eastern shore of Loch Long, running in the direction of the faults on the peninsula. This fault shifts to a considerable distance a felsite dyke which runs in a north-westerly direction into the loch. These faults probably date back to a remote period, before the excavation of the ancient river valleys which are now occupied by the two lochs, but appear to be younger than the intrusion of at least the felsite dykes. Similar dykes in Ayrshire and Cumbrae are of Carboniferous Age.

There are few better examples of a glaciated rock surface than just the quarter-mile of shore intersected by the faults. The hard, compact schists of the present beach have here been protected from the weather up till the time of the last elevation of the land, and have suffered but little wear since the glacial period, while even on two of the higher beaches there are glaciated surfaces still comparatively fresh. A remarkable exception to this appearance, however, occurs in a tract of shore about 100 feet wide, bounded by two of the faults. The rocks here present all the appearance of having slipped downwards between the faults since the glaciation of their surfaces. On the north side the apparent slip is about 10 feet, and on the south side about 6 feet, while there is another apparent slip of about 5 feet between. It is to be noted, however, that the apparently slipped area is more or less divided into tabular masses by jointing, and it is perhaps more likely that, having been powerfully crushed during early earth movements, this portion has yielded to the erosive action of the surf during the time of the 25 feet beach, than that any real slip has taken place since glacial times. The peculiarly serrated outline of the hill ridge, as seen from the other side of Loch Long, is also probably due to the weathering down of similarly crushed areas bounded by east and west fault fissures.

During the Ice Age the glacier filling the glen of Loch Long appears to have been of greater volume than the corresponding

Digitized by Google

glacier in the glen of Loch Goil. From sea-level upwards, for over 1000 feet, frequent exposures of ice-smoothed rock surfaces indicate that the ice-flow was parallel to Loch Long, and invaded the glen of Loch Goil for at least a mile above the southern point of the peninsula. The glaciation of the Loch Long shore and that of the Dog Rock (one of several fine *roches moutonnées*) at the point, show unmistakably that here the Loch Goil ice has not had the slightest influence in deflecting the course of the larger stream. Rounding the point into Loch Goil, the contrast is at once very striking. Instead of flowing, ice-worn surfaces, the rocks here present a broken, cliffy aspect, indicating that the direction of the ice-flow has been from off the land down into the loch. A little further on, in Corran Bay, the hill dips into the loch with a straight, steep slope, which for half a mile is covered with a thick deposit of boulder clay, down which the ice must also have slid into the bed of the loch.

Beyond the brow of this slope, about a mile from the shore, and at an elevation of some 900 feet, there lies a lonely lochan in a true corrie or rock-basin. This may possibly owe its existence to the occurrence of one or more crushed areas, which would offer a diminished resistance to the erosive action of the ice. There is abundant evidence of such action in a direction parallel to Loch Long on the rocky ridges surrounding the lochan, but any which may exist at the lochan itself are hidden under a thick covering of spongy moss.

The western horn of Corran Bay is again a bold, rocky precipice, on which, though a mile above the confluence of the lochs, appears the first indication of the presence of a glacier coming down Loch Goil. This appears to have been the place where the two glaciers coalesced, and from this point onwards towards Lochgoilhead the western sides of the peninsula are generally comparatively smooth, soil-covered hill-slopes, sustaining often an abundant growth of natural wood.

Although composed of the same hard, crystalline schists, there is a marked contrast between the hills forming the eastern flank of the peninsula and those on the opposite side of Loch Long—the former bold, bare, and rugged in the extreme, the latter, for the most part, clothed with a mantle of boulder-clay,

Digitized by Google

and presenting smooth-flowing outlines such as are characteristic of the Southern Uplands. When the bare rock does appear on the east shore of the loch it hardly presents the same intensely glaciated appearance as it does on the west side. The appearances all go to show that, while the movement of the ice has certainly been down the loch, the stream has been steadily pressed against the western side. This was doubtless due to the fact that between Loch Long and Loch Lomond there is a mountainous tract of over 30 square miles at a general elevation of over 2000 feet, which must have been a great gathering ground for snow, whereas the hills both on the peninsula and on the west side of Loch Goil are comparatively narrow ridges, and must have formed but indifferent nurseries for glaciers. At the head of the Gareloch the elevated tract referred to sinks rapidly towards the south, and the ice descending its slopes would follow the line of the least resistance south-eastwards through Glen Fruin, while the combined Loch Goil and Loch Long glaciers, relieved from its pressure, would spread over the Rosneath peninsula and fill the valley of the Gareloch. It will thus be noted that where the hillsides have been subjected to severe lateral pressure by ice descending higher mountainous tracts from a direction at right angles to the flow, there we find the naked rock; but where screened from such pressure we find the boulder clay.

Erratic blocks do not seem to be very common on the peninsula. A few well-rounded specimens of diorite and of the characteristic granite of Garabal Hill are to be seen on both its shores, also an occasional well-worn block of a hard, gnarled biotite schist with pink felspar bands, probably from the ring of indurated schists surrounding the plutonic complex of Garabal Hill. Most of the loose blocks, as also the boulders in the clay, appear to be of local origin.

Although dykes, both acid and basic, are numerous on the opposite shore of Loch Long, very few are to be seen on the peninsula itself. Near the point a dolerite dyke crosses in a south-westerly direction from loch to loch. A great dyke of dolerite about 80 feet thick, mentioned by Bryce in his "Geology of Clydesdale," crosses Loch Long in a south-westerly direction, but just misses the peninsula. This dyke has been traced across

Digitized by Google

Loch Lomond for 50 miles into the Ochil Hills, and across Loch Eck for 10 miles more in the other direction. Both the 25 feet and the 50 feet beaches may be traced as rocky shelves along the Loch Long shore for a short distance from the point of the peninsula, but, as a rule, this feature is almost entirely absent, except where a hill-stream has carried its load of rock fragments down the slope and formed a delta above the level of the present beach. These deltas form the sites of the only dwellings, some half-dozen in number, on the peninsula. On the opposite shore of Loch Long the 25 feet beach is fairly continuous, while the 50 feet one is frequently, and the 100 feet one occasionally, in evidence.

A late chapter in the history of the park is suggested by the name of the tract of country of which it forms a part, viz., "Ardkinglas," "the point or height of the grey dog," indicative of a time when packs of wolves infested its boskier recesses. Doubtless they lingered long in the district, the wild nature of which would render the task of exterminating them a most difficult one. At length, however, the grey dog gave place to the red deer, and the red deer in turn to the black-faced sheep. By and by, were a reliable flying machine but invented, the park might become a suitable habitat for the toil-worn citizens of Glasgow.

Digitized by Google

No. III.—A Glaciated Rock Surface at Lugton, North Ayrshire.

By J. W. Gregory, D.Sc., F.R.S., University, Glasgow.

[Read 11th January, 1906.]

1. The Striation and Glacial Grooves.
2. The Overlying Boulder Deposit.
3. The Direction of the Ice Movement.
4. Nature of the Ice Agent.
5. The Limited Glacier Abrasion and Ascending Ice Movement.
6. The Origin of the Lugton Glacier.
7. The Age of the Lochwinnoch and Loch Libo Gaps.

Mr. James Reid, of the Lugton Lime Works, has kindly called my attention to a large surface of glaciated limestone at Lugton, of which he has presented some fine slabs to the University collections. As the striation is of exceptional perfection, and several of its features clearly show the direction of the ice movement at this locality, its evidence seems worthy of record.

Lugton is a station twelve miles to the south-east of Glasgow, in northern Ayrshire. It is in the valley of the Lugton Water, which flows south-westward along a band of the Lower Carboniferous Limestone series, let down by trough-faulting between hills formed of porphyrites belonging to the Calciferous Sandstone series. The glaciated surface occurs in a limestone quarry, about 200 yards south-west from the railway station, and on the right bank of Lugton Water. Its altitude is about 376 feet above sea-level. Lugton Water rises 3 miles to the north-east, a little above Loch Libo, which is practically its source. The Lugton valley is followed by the Glasgow & South-Western Railway line to a pass, at the level of a little over 400 feet, by which it crosses to the valley of the Cowdon Burn, a tributary of the Cart; and it thus descends to Neilston and Barrhead. The Lugton Limestones contain a rich fauna

Digitized by Google

Digitized by Google

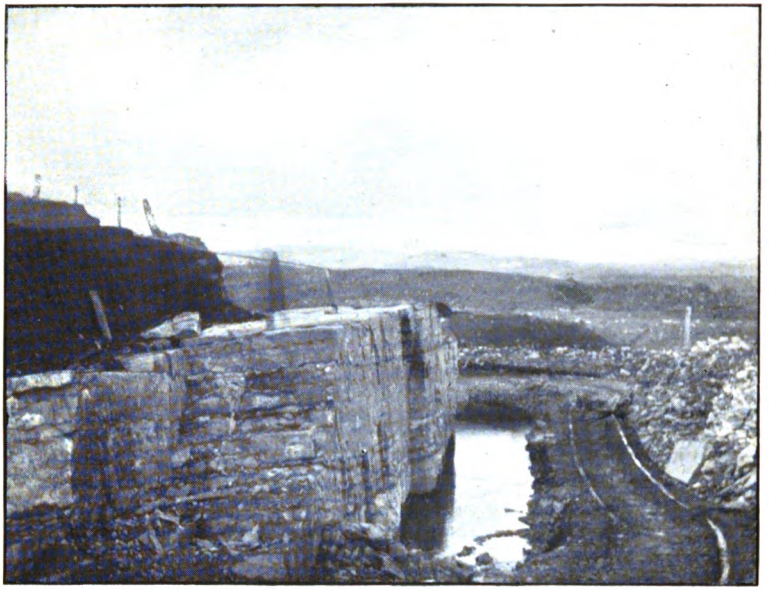


Fig. 1.—Quarried face of the glaciated rock surface in the Lugton limestone quarry.

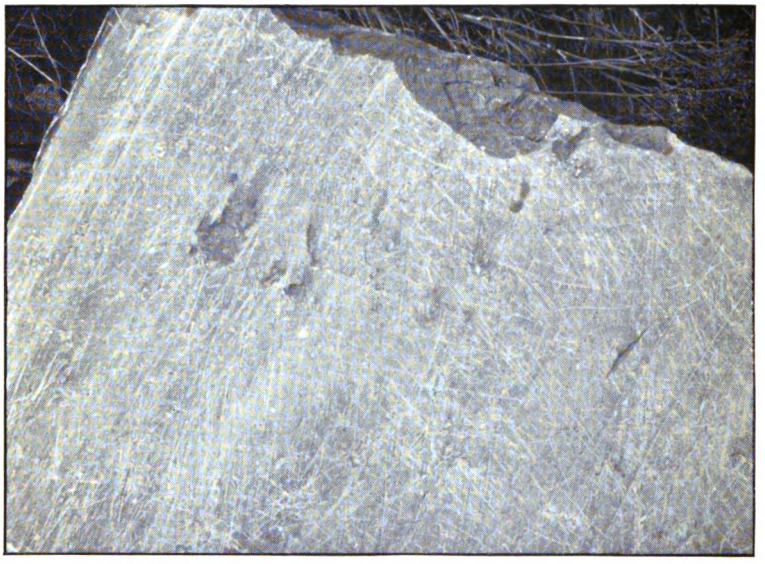


Fig. 2.—Photograph of part of the glaciated rock surface showing the predominant parallel striæ from south-west to north-east, and the shorter, irregular, transverse striæ, some of which are crescentic.

Digitized by Google

of corals, brachiopods, and fish remains, which indicates that the beds belong to the Lower Limestone series.

1. The Striation and Glacial Grooves.

The glaciated surface is on the south-eastern side of the Lugton valley, but the surface of the limestone slopes downward to the south-east, at angles of from 7 degs. to 12 degs., the average slope being about 10 degs. The surface probably represents the south-eastern side of a huge *roche moutonnée* (Plate I., fig. 1). The limestone at the south-western end of the quarry dips 12 degs. to east-south-east, but at the northern end the bedding becomes horizontal, and there is sign of a slight rise to the north-east. The glaciated surface exposed in the quarry, now in part removed, was from 12 to 14 yards in width, and it is from 70 to 80 yards in length.

The wider part of the surface exposed at the time of my visit was 33 yards long. It is covered by a sheet of coarse sand and clay containing boulders, which look more like normal morainic material than the boulder clay of the Glasgow basin. The removal of the boulder deposit leaves the striæ exposed in exquisite preservation on the polished surface of the limestone. Most of the striæ run from south-west to north-east, and some of them continue in a straight line for several yards. Most of them are approximately parallel, and the long major striæ vary within about 15 degs. from the average north-easterly direction. The major striæ are crossed by transverse striæ* (Plate I., fig. 2), some of which are in concentric series, covering about a quadrant in arc; other cross striæ are short and straight, and are at right angles, or at a high angle, to the predominant striation. In parts of the surface the cross striæ are rare and faint. The series of transverse concentric striæ clearly indicate the twisting of boulders. As these concentric groups are not infrequent in the quarry, they suggested the screwing move-

* Cross striation is fairly common in the Glasgow district. Cases have been described, *e.g.*, by Dugald Bell, "Notes on the Glaciation of the West of Scotland, with Reference to some recently observed Instances of Cross Striation."—*Trans. Geol. Soc., Glasgow*, vol. iv., pt. 3, 1874, pp. 300-310.

Digitized by Google

ment of half-floating, stranded ice. The striæ themselves, however, are very different in shape from those made by ice floes which have grounded upon the shore. In places the cross striæ are straight, and so numerous that the surface of the limestone appears white, owing to the closeness of the cross hatching.

The long striæ are deepest and narrowest at their south-western ends; they become broader, shallower, and with ragged, broken edges at their north-eastern ends. The striæ may be grouped into three series—(1) an early series, running from west to east, down the slope of the glaciated surface; (2) they have been largely obliterated by striæ of the long, parallel, south-west to north-east series; the third and last set include the concentric and the smaller striæ running west and east. The last set probably represents the movement of the ice down the sloping surface of the limestone of the *roche moutonnée* after the onward flow had ceased.

In addition to the striæ, there are wide, coarse grooves, one of which is 3 feet long and 11 inches wide; the direction of all the grooves exposed at my visit was south-west to north-east and parallel to the main striation.

2. The Overlying Boulder Deposit.

The overlying boulder bed is of a very sandy, coarse-grained material. The majority of the boulders, especially the large ones, are of local origin, and many of them are unpolished, unrounded, or unscratched. Some of them have obviously been moved only from a short distance from the south-west. The smaller boulders and pebbles are rounded, scratched, and of more remote origin. They include coarse red sandstones, pebbles of vein quartz, boulders of limestone and black shale, and an occasional pebble of metamorphic rock. I did not see any specimens of the typical Highland schists, which are so conspicuous in the Glasgow basin. This boulder bed was probably laid down by the ice that cut the striæ, for the extreme freshness of the scratches and the unweathered nature of the surface on which they occur show that the limestone

Digitized by Google

surface has never been exposed to the air for any length of time. Blocks of the limestone which have been left exposed to the air in the quarry for a short time are already stained yellow, and the scratches spoiled by weathering. It is clear that the glaciated surface was either formed under water, or was immediately covered by mud from the ice that made the scratches.

3. The Direction of the Ice Movement.

I went to the quarry in the belief that the ice movement in this district was from north to south, or from north-east to south-west. This expectation was founded on the direction of striæ in the Libo Pass, recorded on the Geological Survey Map, Sheet 22,* with the arrow pointing to the south-west. Sir Archibald Geikie's map† shows the ice movement over Renfrewshire and this part of Ayrshire as either from north to south or having a slight trend to the west of south. The Geological Survey of Scotland Memoir‡ also gives the general direction as from north to south, with special mention of localities above Largs, where the direction is to south 25 degs. west and to south 2 degs. east. The same general direction of the ice movement is given in Mr. John Smith's list§ of records in northern Ayrshire, where, at Fairlie, the direction is from north to south, and in the valleys of north-eastern Ayrshire the direction is down the valley from north-east to south-west.

The evidence of the Lugton Quarry is, however, absolutely convincing that the ice movement which polished this limestone surface was from south-west to north-east. There may have been an earlier movement from north to south over this district; but this quarry gives evidence only of the one glaciation. The north-eastward flow of the ice is proved by the following evidence:—

(1) The striæ are deepest and narrowest at their south-

* Another striation in the opposite direction is, however, recorded in the same map, but I had overlooked it, until reference to the 6-inch Geol. Survey Map, Renfrewshire, Sheet XVI., which marks striæ pointing to the east-north-east, at the head of the carboniferous trough of Lugton.

† "Scenery of Scotland," edition 3, 1901, Plate IV.

‡ Sheet XXI., pp. 132, 134, 137.

§ J. Smith in the "Fauna, Flora, and Geology of the Clyde Area."—*Brit. Assoc. Handbook*, 1901, p. 524.

Digitized by Google

western ends, and become shallower, broader, and more ragged to the north-east, showing that the point of the scratching stone was gradually worn away as it was carried north-eastward.

(2) The glaciated surface passes over the edges of successive limestone beds, owing to their eastern dip. The harder rocks stand up in steplike elevations, a foot or two in height. The south-western faces of these steps are highly polished and their edges bevelled, clearly showing that they were exposed to ice coming from the south-west. On the other hand, the slight depressions that occur on the north-eastern side of occasional projecting bars of limestone are rough and unscratched; the ice, having been raised by the bar, did not press with much force on the protected surface behind it.

(3) Especially convincing evidence is given by a number of limestone boulders which have been piled up in a heap, over one that had lodged against a limestone step (Plate II., fig. 2). They are lying tilted downward to the south-west. The sand and stones between them are pressed up and bent in little overfolds pointing to the north-east. The evidence is conclusive that this heap of boulders was being carried from south-west to north-east, and was jammed against the projecting ledge of limestone.

(4) The absence of any conspicuous boulders of the Highland schists—which occur so abundantly in the boulder clay around Thornliebank—on the northern side of the hills at the head of Lugton Water—also supports the movement of the ice from the south. If the ice had been coming down from Loch Libo, the porphyrites would doubtless have been more abundant and in larger boulders than the Carboniferous sediments and limestone, which are the conspicuous materials in the drift. All the included rocks that I noticed might have been derived from the area to the south and south-west. An occasional specimen of the Highland rocks would not be surprising, for some of them must have been carried south, down the Firth of Clyde, in early glacial or pre-glacial times, and hence they may have passed into the Lugton area from the south-west. Many fragments of them occur in this district, probably derived from old river gravels.

The rapid increase in the scarcity of erratics of northern

Digitized by Google

Digitized by Google

Fig. 1.—A vertical glaciated surface, facing the north-west. An undercut glacial groove in the face of the limestone extends from $\frac{3}{4}''$ to $1\frac{1}{4}''$ to the right of the handle of the hammer.

Fig. 2.—A group of boulders piled against a step in the limestone. The boulders in the group are sloping downward to the south-west. The moraine matter between them is thrown into overfolds, indicating movements from south-west to north-east.

Digitized by Google

origin to the south of the Renfrewshire hills is shown by the table given by Craig,* which includes the following data:—

	Metamorphic.	Old Red Sandstone.	"Traps."	Carboniferous.
Greenock, Garvel Park, -	20·37	61·10	17·93	
Planetreeyetts, - -	16·86	4·37	78·24	
Paisley, Seedhills, -	9·71	24·5	39·44	25·51
Loch Libo, Neilston, -	14·2	14·3	61·64	11·21
Shelford, - - -	8·63	4·11	75·52	15·85
Lochwinnoch, Nethertrees,	12·13	11·30	62·89	15·37
Beith, Bogside, - -	10·60	6·41	74·82	7·97
Dunlop, Netherton, -	4·33	7·19	44·87	43·61
Stewarton Flowers, No. 1a,	6·6	7·7	72·33	16·61
No. 2a,	4	3	69	24
No. 3a,	3	1·20	63·80	29·89
Kilmarnock, Bonnington,	1·6	1·44	79·75	17·25
Windyhouse, Beith, No. 1a,		11·13	55·59	43·28
No. 2a,			26·70	73·75
No. 3a,		5	33·13	61·87

4. Nature of the Ice Agent.

The groups of concentric striæ render it necessary to consider the possible action of floating ice; but the remarkable regularity of the long striæ shows that they were made by some agent advancing slowly, steadily, and uniformly, and is, therefore, more likely to have been a glacier than floating ice. The most convincing evidence is supplied by a secondary limestone *roche moutonnée*, of which the vertical face is exposed to the north-west; this exposed face has not only been regularly scratched, but it has been undercut by a deep glacial groove, which has been polished as regularly as the rest of the surface (Plate II., fig. 1). This groove at least must be due to ice in the plastic condition of glacier ice, which was forced against the side of the valley, and cut this deep groove along a band of softer rock.

*R. Craig, "On the Glacial Deposits of North Ayrshire and Renfrewshire."—*Trans. Geol. Soc., Glasgow*, vol. iv., part 2, 1873, p. 161.

Digitized by Google

5. The Limited Glacier Abrasion and Ascending Ice Movement.

Two further points of interest in this exposure are (1) its illustration of the limited extent to which glacier ice, under some circumstances, wears away smooth rock surfaces; for with all its powers of polishing and scratching the ice has not planed down the small steps in the limestone that crossed its path. The ice has polished the surface and rounded off the projecting edges, but it has ridden over small obstacles instead of cutting them away.

(2) The upward movement of the ice. The long striæ on this surface pass obliquely across it, keeping on an absolutely horizontal course; most of the cross striæ run down the slope, though some, especially of the curved concentric striæ, were cut up the slope. But if the ice moved far along the Lugton valley from south-west to north-east, it must have had a slight uphill movement, and the included boulders suggest that the direction indicated by the striation was not confined to the neighbourhood of the quarry, but held through the Lugton valley.

6. The Origin of the Lugton Glacier.

The form of the ice-worn surfaces near Caldwell, Loch Libo, and Shelford suggest that at the very head of the Lugton valley the ice movement was north-eastwards. The Lugton Glacier may have been formed on the Renfrewshire hills around the Hill of Stake and Misty Law, whence it may have flowed first south-eastward until it was blocked by the high ground between Lugton and Dalry, by which it was forced to the north-east. The ice may, however, have come from Arran. In that case boulders of Arran granite might be expected; but it is possible that the ice may have been the end of an Arran glacier which lapped up against the Ayrshire coast to the height of 400 or 500 feet.

7. The Age of the Lochwinnoch and Loch Libo Gaps.

The direction of the ice movement raises the question as to

Digitized by Google

the origin of the two low valleys—that of Cowdon Burn and Lugton, and that of Lochwinnoch, which connect the basins of Glasgow and North Ayrshire.

The view has frequently been expressed that at one time the Glasgow basin had an outlet into Ayrshire through the Loch-

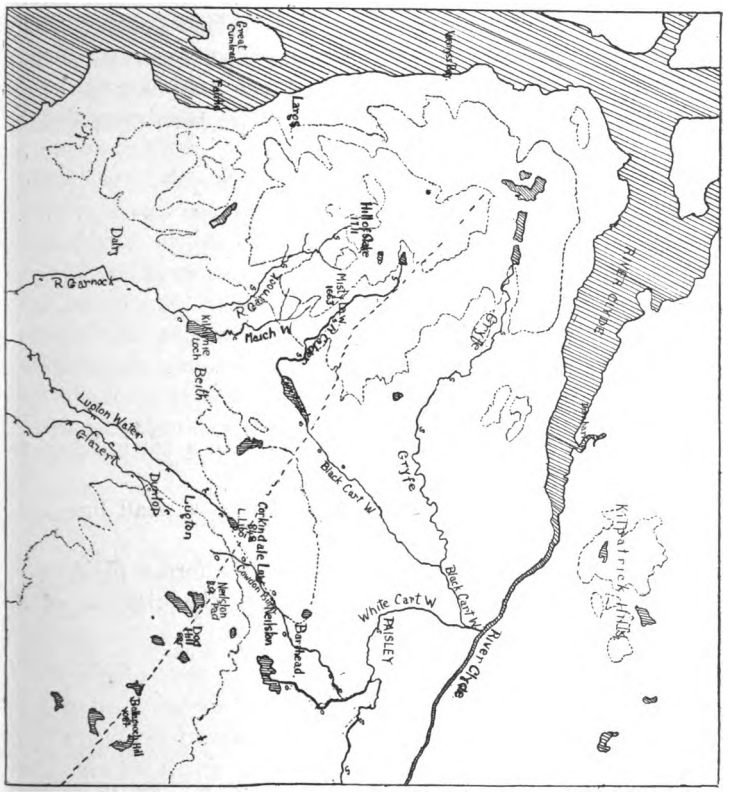


Fig. 1.—Sketch map on the scale of 6½ miles to 1 inch. The line of short strokes running from north-west to south-east through Neilston Pad, Dod Hill, and Ballagioch Hill represents the general position of the former divide.

winnoch gap. However that may have been, the general geographical evidence renders it probable that the Garnock, Lugton, and Glazert were consequent rivers, flowing to the south-west down the Renfrewshire and Neilston hills; the

Digitized by Google

northern face of the hills was the steepest, the original divide being near the steep scarp, which forms the southern boundary of the Glasgow basin (fig. 1). The Black Cart and the upper part of the White Cart are obsequent rivers that have cut their way back and beheaded the upper parts of the Garnock and the Lugton, while the Gryfe and the Lower Cart are subsequent rivers. The Garnock and Lugton valleys seem to me unquestionably pre-glacial in date; and the terraces that must have been formed before the upper waters of the Garnock had been diverted into the Glasgow basin would have been destroyed by glacial erosion.

ILLUSTRATIONS.

Plate I.

1. Photographs of the Quarry.
2. Cross Striation.

Plate II.

1. A secondary *roche moutonnée*, with a vertical face to the north-west.
2. Group of boulders piled up against a small limestone step.

Fig. 1. Sketch map with course of the former divide.

For the photographs I am indebted to the kindness of S. Fingland, Esq.

Digitized by Google

No. IV.—The Extension Westwards of the Necropolis Intrusion. By Frederick Mort, M.A., B.Sc., F.G.S., *Hon. Secretary.*

[Read 8th March, 1906.]

Some time ago Mr. Macnair, F.R.S.E., in exhibiting the Pratt collection of microscopic slides of dolerite recently presented to the Corporation, commented on the resemblance that a section of dolerite from Miller Street bore to the well-known dolerite of the Necropolis. Considerable doubt was expressed as to the identity of the two rocks, and the opinion was given that the Miller Street occurrence was a dyke. Among those who have conducted excavations in this region also this occurrence of whin is known as the Miller Street dyke. The object of the present paper is to examine the evidence bearing on the question, and to endeavour to establish the probability of the Necropolis intrusion extending as far west as Miller Street.

There is, of course, no opportunity of obtaining direct field evidence on the matter, as the area in question is completely built up, but indirect field evidence will be given, showing that dolerite occurs in several places between Miller Street and the main body of the intrusion.

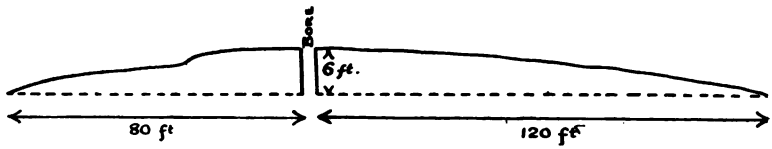
The Necropolis intrusion consists of a huge mass of dolerite intruded into the Millstone Grit series, and extending for some miles east of Glasgow.

The intrusion seems to stop rather abruptly just at the Necropolis, but on the Survey 6-inch map a detached mass of dolerite is shown some distance west of the main rock.

From information available since the map was published, it can be shown that this part is not quite accurate. The tunnel of the North British Underground Railway should penetrate the rock shown on the map at Balmano Street, but no dolerite was found at this part. The dolerite, however, was found a little farther on at Nicholas Street, an occurrence which is not noted on the map. The shape of the top part of the dolerite at this point is instructive, and is shown in the following sketch. It resembles the top of a sill much more than the top of a dyke.

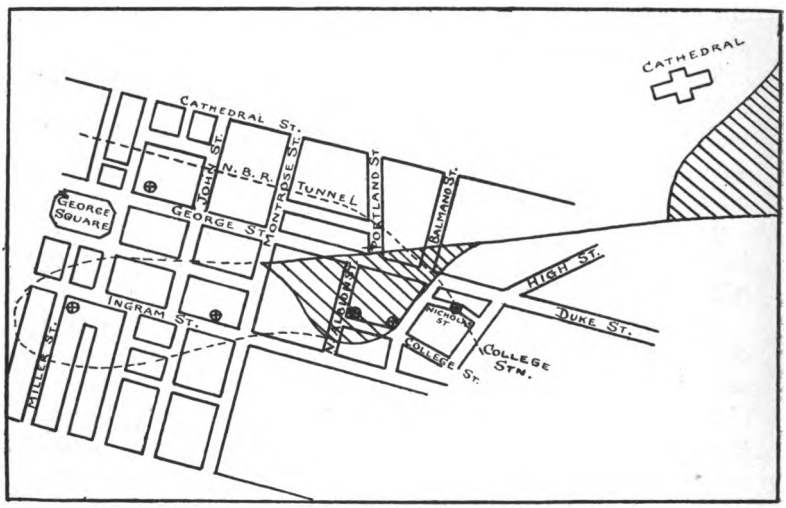
Digitized by Google

Dolerite occurs again in North Albion Street, in College Street, in Ingram Street, and in George Street. West of the main Necropolis mass, therefore, dolerite can be found in at



Upper surface of whin at Nicholas Street from information supplied by engineers of N.B. tunnels.

least six localities, and it seems more reasonable to think that these are merely outcrops of one large intrusion rather than so many dykes. The petrographical evidence which will next be adduced helps very much to strengthen this conclusion.



Sketch map of part of Glasgow. Shaded parts represent dolerite shown on Survey map; crosses within circles show outcrops of dolerite mentioned in paper.

The Necropolis rock is, fortunately, a dolerite of a peculiar kind, and its divergences from the normal type furnish valuable aids to its identification. A detailed description of the

Digitized by Google

rock will not be attempted, but attention directed rather to its abnormalities.

As has been mentioned, dolerite occurs about half-way between the Necropolis and Miller Street. A number of thin sections have been made of samples of this rock taken from an excavation at North Albion Street. If, now, we compare the Necropolis rock with this North Albion Street dolerite, we find a remarkable resemblance. The minerals of the Necropolis rock are augite, plagioclase felspar, chlorite, magnetite, biotite, calcite, needles of apatite, hornblende, pyrites, and an isotropic material, either glass or perhaps analcite.

The minerals of the North Albion Street dolerite are absolutely the same, with the exception of hornblende, which, however, is absent in most of the sections from the Necropolis.

The structure of the Necropolis rock is peculiar. Most dolerites show an ophitic structure—that is, the felspar has crystallised earlier than the augite, and laths of felspar are therefore found surrounded by augite. The opposite is the case with the Necropolis intrusion. The augite has formed before the felspar and appears in well-shaped idiomorphic crystals. The North Albion Street dolerite shows exactly the same peculiarity.

The colour of common augite is brown, in various shades. In ordinary light, however, the Necropolis augite has a distinct purple tone, which is found also in the augite from North Albion Street. Augite, as a rule, is not pleochroic, but the augites in both the Necropolis and the North Albion Street dolerites are faintly yet clearly pleochroic. The pleochroism is best seen in cross sections which change from purple-brown to yellow.

The scheme is as follows:—

α = yellow.
β = purplish-brown.
γ = purplish-brown.

In nearly all the specimens of Necropolis rock the augite is partly decomposed to chlorite. In many sections the chlorite has a characteristic habit. It appears often as circular, radiating aggregations, and sometimes with a worm-shaped

Digitized by Google

structure. We find exactly the same habit in the North Albion Street dolerite.

A peculiar feature of the Necropolis rock is that the augite in many cases has been considerably crushed, and appears as a broken granular mass. This crushing took place early in the history of the rock, for the augite granules are sometimes enclosed in unbroken felspar crystals.

In the North Albion Street rock the same phenomenon is apparent, but to an even greater extent.

In short, these two rocks are so similar that there can be little doubt that the North Albion Street dolerite is an integral part of the main intrusion.

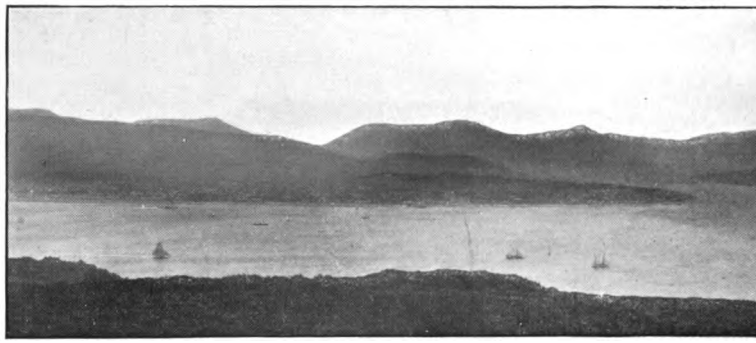
When we come to the Miller Street rock we have, unfortunately, very little material for examination, only one slide being available. Yet here again we find the same peculiar features of the rock appearing. The structure and order of crystallisation, the presence of the same minerals, the colour and pleochroism of the augite, and the decomposition products recall at once the characters of the main intrusion—in short, the whole facies of the rock is the same. In fact in some points the Miller Street rock resembles the Necropolis rock even more than does the North Albion Street dolerite.

It should not be forgotten that the microscopic characters described above are not common, and to find not one but all these abnormalities possessed by three quite distinct and unconnected outcrops in such a small area seems quite incredible.

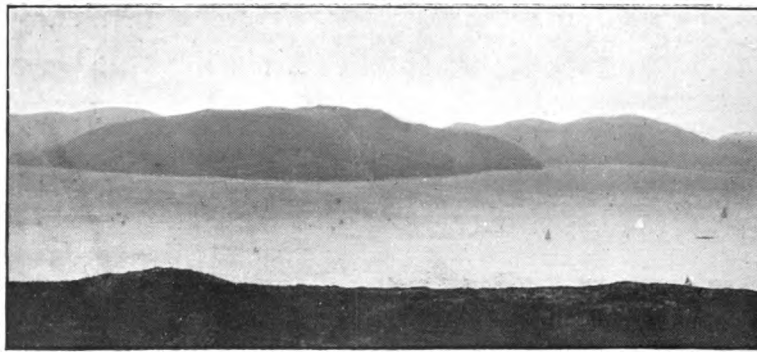
Both lines of evidence point unmistakably to the same conclusion, that the Necropolis intrusion extends as far west as Miller Street, and that the so-called dyke of the latter locality, as well as the intermediate outcrops, are in reality integral parts of the main intrusion.

Digitized by Google

Digitized by Google



Highlands from Dunoon to Kilmun.



Highlands from Kilmun to Loch Long.

Digitized by Google

No. V.—The Southern Highlands from the Clyde Valley.

By Frederick Mort, M.A., B.Sc., F.G.S., *Hon. Secretary*, and John Frew, M.A., B.Sc.

[Read 10th May, 1906; 11th October, 1906; and 13th June, 1907.

A good view of the Southern Highlands may be had from almost any elevated position to the west of Glasgow. It adds considerably to the interest of the view if the outstanding peaks can be recognised, and it is a matter of regret that comparatively few can identify mountains the names of which are as familiar to them as their own. In excursions of scientific societies, when a favourable view of the Highlands has been obtained, we have almost invariably found that differences of opinion have arisen regarding even peaks with a marked individuality. An outline drawn from accurate measurements is all that is needed for most purposes of identification, and, on finding that, to the best of our knowledge, nothing of an exact kind had been done for the district, we attempted to make good the deficiency.

The method employed in constructing the drawings was the same in all cases. The angles were taken by means of a theodolite, both horizontal and vertical readings being noted. These angles were then accurately transferred to maps of the district, and now, for the first time, our belief in the infallibility of maps was distinctly shaken. Scarcely two of them agreed accurately enough for our purpose, until we found, in the map of the Clyde Valley published by the British Association at their last Glasgow meeting, a representation of the district which best met our requirements. The actual contours of the hills were drawn each time from a series of sketches and photographs made on the spot.

The first figure in each drawing shows the visible horizon in its true angular relations. When an observer is looking from any position, the hills in the distance sweep round in a great circle, of which he is the centre. We have, therefore, drawn them on the arc of a circle, and lines joining the centre of the circle to any two peaks will show the true angle between the peaks. If, however, the observer looks only at a small part of the horizon, it appears straight, and therefore, in order to make

Digitized by Google

identification easier, we have in succeeding drawings straightened the horizon and enlarged the scale considerably.

Observations were taken from three stations—one in the north, one in the south, and the last in the centre of the Clyde Valley. From a comparison of the drawings it should be possible to obtain an idea of the mountains visible from most intermediate positions.

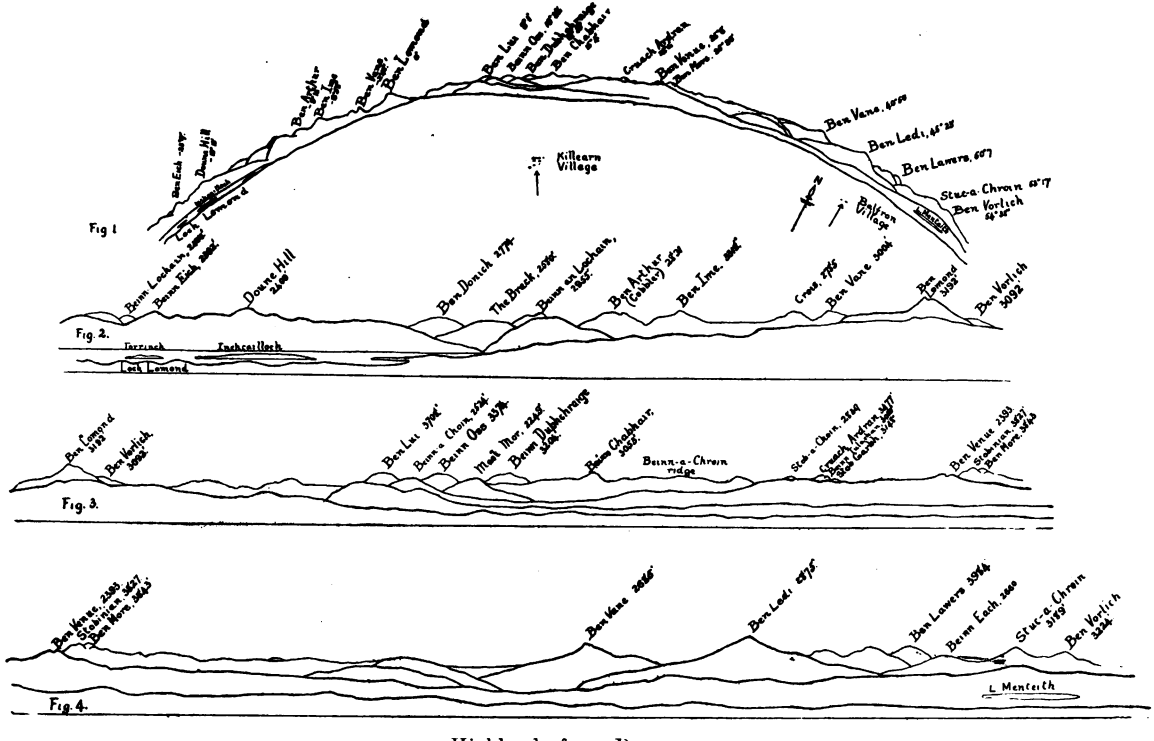
Highlands from Dumgoyn.

Dumgoyn (1401 feet), a steep isolated hill of volcanic agglomerate near the western termination of the Campsie Fells, was chosen as a suitable spot from which to make our first measurements. In several respects it is superior to any other place in the northern Clyde Valley. It is far enough west to be clear of both Kilpatrick Hills and Campsie Fells. It is not near enough the Highland line for the view to be confused, as is the case to an observer in the Highlands, who is apt to be perplexed by the sea of peaks around him. Lastly, its exact position can be easily fixed on the map. As Ben Lomond is the summit most easily recognised, the angles were measured from it. Angles to the right of it in fig. 1 are considered positive, and those to the left negative. The table on p. 25 gives the names of the mountains visible from Dumgoyn, with their heights and angular distances from Ben Lomond.

It is obvious that the apparent height of a mountain, as shown in the drawings, does not necessarily agree with the real height, the distance from the eye being an important factor. Several of the hills seen from Dumgoyn have a distinct individuality that makes identification easy. Ben Venue has a doubly peaked summit, the height of the eastern spur being only 7 feet less than that of the western. Ben Ledi appears the most massive mountain, its nearness giving it a conspicuousness to which it is not entitled by its actual height. Ben Vane ($+40° 50'$) is distinctly flat-topped. Ben Vorlich ($+1° 46'$) has almost the appearance of being a shoulder of Ben Lomond. Ben More and Stobinian look like one peak, but a field-glass separates them quite distinctly.

Ben Lui, Beinn Oss, and Beinn Dubhchraige, three splendid

Digitized by Google



Highlands from Dumgoyn.

Digitized by Google

Digitized by Google

peaks in the very background, are all connected, and really form the three culminating points of a single ridge.

Name of Peak.	Angle from Ben Lomond.	Height in Feet.
Beinn Lochain,	−23° 33′	2306 feet.
Beinn Eich,	−23° 9′	2302 ,,
Doune Hill,	−19° 13′	2409 ,,
Ben Donich,	−14° 48′	2774 ,,
The Brack,	−12° 56′	2580 ,,
Beinn an Lochain,	−10° 54′	2955 ,,
Ben Arthur,	− 9° 15′	2891 ,,
Ben Ime,	− 6° 58′	3318 ,,
Crois,	− 4° 6′	2785 ,,
Ben Vane,	− 2° 48′	3004 ,,
Ben Lomond,	0° 0′	3192 ,,
Ben Vorlich,	1° 46′	3092 ,,
Ben Lui,	9° 1′	3708 ,,
Beinn a Choin,	9° 58′	2524 ,,
Beinn Oss,	10° 33′	3374 ,,
Maol Mor,	11° 46′	2249 ,,
Beinn Dubh-chraige,	12° 39′	3204 ,,
Beinn Chabhair,	15° 4′	3053 ,,
Stob a Choin,	21° 15′	2839 ,,
Cruach Ardran,	22° 3′	3477 ,,
Beinn Tulachan,	22° 15′	3099 ,,
Stob Garbh,	22° 27′	3148 ,,
Ben Venue,	25° 6′	2393 ,,
Stobinian,	26° 4′	3827 ,,
Ben More,	26° 26′	3843 ,,
Ben Vane,	40° 50′	2685 ,,
Ben Ledi,	45° 23′	2875 ,,
Ben Lawers,	50° 7′	3984 ,,
Beinn Each,	51° 21′	2660 ,,
Stuc a Chroin,	53° 17′	3189 ,,
Ben Vorlich,	54° 38′	3224 ,,

From an elevated position within the Highland area, at a first glance there is revealed on all sides a bewildering chaos of mountain and valley. There seems to be no order, no arrangement, no underlying causal principle in this tumbled sea of hills. A closer examination, however, shows that the mountains, as a whole, reach a fairly uniform height. If the material carved out of the valleys by river erosion were replaced, we should see an almost level table-land. This represents a former base-level of erosion, out of which, by upheaval and denudation, the present outlines of mountain and valley have been sculptured. That the table-land was produced by erosion, and

Digitized by Google

not by one simple tectonic movement, is shown by the fact that planes of foliation and bedding strike at all angles to the surface. Fault-plane and thrust-plane, syncline and anticline, were alike planed across and levelled by the two all-powerful geological forces, time and the weather. The old Highland plateau can be particularly well seen from points outside the Highland frontier, such as the ones from which the accompanying drawings were made.

Highlands from Gourock.

If the observer now changes his position to the south of the Clyde, he obtains quite a different view of the Highland peaks.

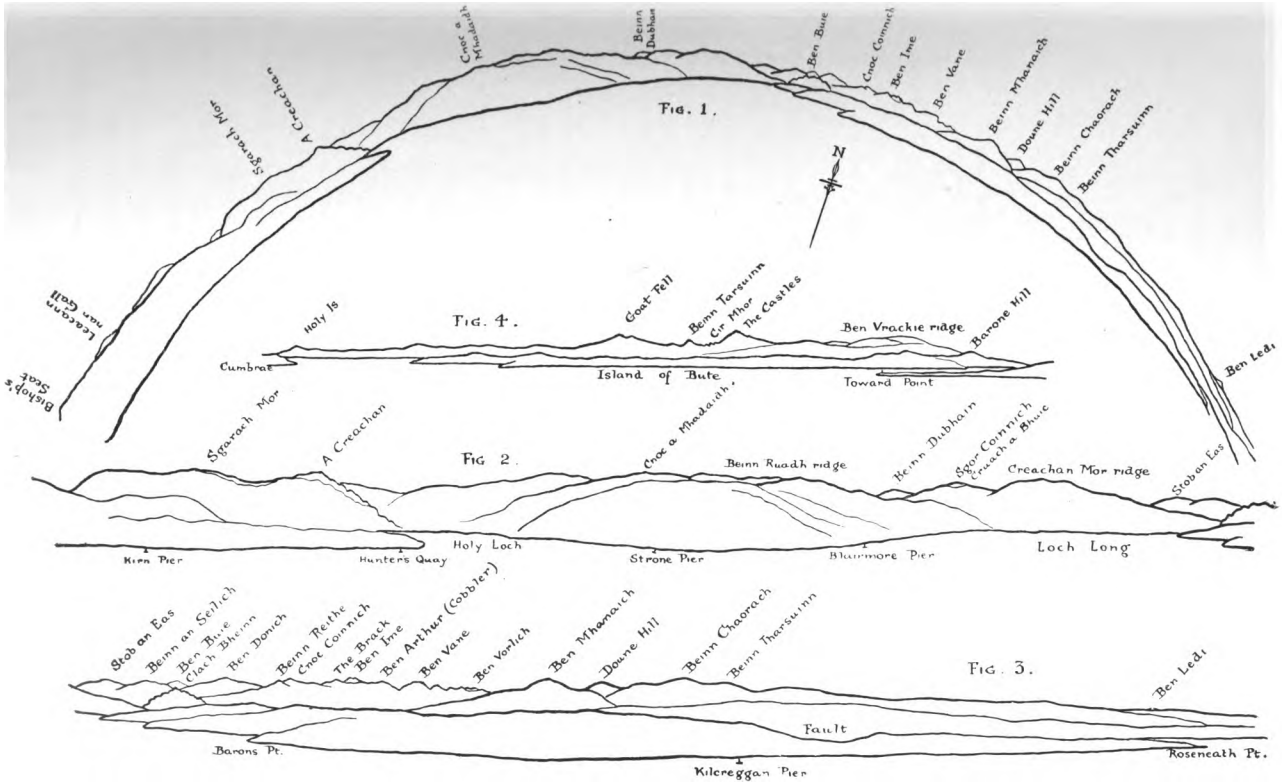
The station from which the following drawings were constructed is a hill about two miles south-west of Gourock. It is the 610-feet summit-level shown on the Ordnance maps just behind Leven Castle. From this point a magnificent sweep of coast-line can be seen, stretching from above Helensburgh, past Dunoon, to Toward Point. South of Toward Point one looks right over Bute to Arran in the distance. The peaks visible, with their heights and angles from Rosneath Point, are given in the table on p. 27.

Figs. 2 and 3 show the same hills as fig. 1, on a scale about twice the size of that of fig. 1. The ridge from Bishop's Seat, above Dunoon, to Glen Lean, in front of Sgarach Mor, is omitted in fig. 2, as Bishop's Seat is the only feature of any importance.

The most interesting mountain group shown in the drawings is undoubtedly the range behind Loch Long. Although few of the summits exceed 3000 feet in height, the mountains are so rugged in outline, the masses so justly proportioned, and the contours so varied that they form as impressive a group as any in the country. The range subtends an angle of only 14°, but to an observer the mountains give the impression of stretching over a much greater extent.

Of this group of mountains, sometimes called the "Alps of Arrochar," the highest and most imposing is Ben Ime. Both Ben Ime and Ben Vorlich are in the background, as is shown in fig. 3. The line of the ridge just in front of them is shown in the drawing, but it may be quite imperceptible to the eye.

Digitized by Google



Highlands from Gourock.

Digitized by Google

Digitized by Google

Such also is the case with several other lines in the drawings. It is only in certain lights that they become visible. For example, on only one day of the three that we spent on the hilltop was it quite plain that Beinn Reithe and Cnoc Coinnich

Name of Peak.	Height in Feet.	Angle from Rosneath Point.
Ben Ledi,	2875 feet	2° 22′
Beinn Tharsuinn,	2149 ,,	23° 23′
Beinn Chaorach,	2338 ,,	25° 26′
Doune Hill,	2409 ,,	29° 5′
Beinn Mhanaich,	2328 ,,	32° 37′
Ben Vorlich,	3092 ,,	35° 40′
Ben Vane,	3004 ,,	37° 28′
Ben Arthur (Cobbler),	2891 ,,	39° 58′
Ben Ime,	3318 ,,	41° 21′
The Brack,	2580 ,,	42° 5′
Cnoc Coinnich,	2497 ,,	44° 20′
Beinn Reithe,	2141 ,,	45° 5′
Ben Donich,	2774 ,,	47° 41′
Clach Bheinn,	1433 ,,	49° 7′
Ben Buie,	3106 ,,	49° 16′
Beinn an t Seilich,	2359 ,,	50° 42′
Stob an Eas,	2400 ,,	53° 15′
Creachan Mor,	2156 ,,	58° 39′
Cruach a Bhuic,	2084 ,,	62° 39′
Beinn Dubhain,	2090 ,,	66° 29′
Beinn Ruadh,	2178 ,,	73° 24′
Cnoc a Mhadaith,	1535 ,,	79° 24′
A Creachan,	1902 ,,	93° 58′
Sgarach Mor,	1972 ,,	99° 21′
Bishop's Seat,	1651 ,,	124° 57′
Barone Hill,	532 ,,	177°
The Castles.	2735 ,,	188° 32′
Cir Mhor,	2618 ,,	189° 26′
Beinn Tarsuinn,	2706 ,,	190° 2′
Goatfell,	2866 ,,	193° 28′
Holy Island,	1030 ,,	208° 30′

were two distinct peaks, and not one. Of the two hills, Clach Bheinn and Ben Buie, Ben Buie is, of course, the more remote. Clach Bheinn is interesting, for it forms the most southerly and best-known point of Ardgoil, Glasgow's new Highland park. Most of the important Perthshire mountains are completely cut off by the high ridges in the foreground. It is only where these diminish towards the east that Ben Ledi becomes visible.

One of the most interesting features of the landscape is seen

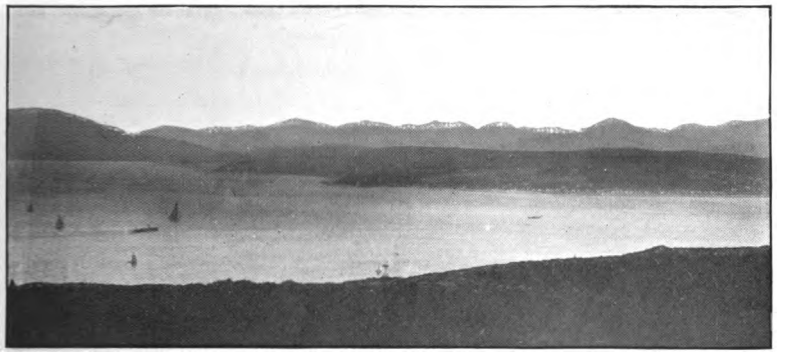
Digitized by Google

in the drawings just east of Kilcreggan Pier. A distinct notch cuts into the low range of hills behind Kilcreggan. This is the groove caused by the great fault that runs right across Scotland. This great crack separates the Highlands from the Lowlands, all the rocks to the north belonging to the Highland schist series. The feature this fault makes in the landscape can probably be seen better from this part of the Firth of Clyde than from any other point in Scotland.

No one can fail to be struck by the great differences in outline of many of the ridges. All the foreground is occupied by low ranges of smooth and rounded contours, the profiles of which sweep down in softly flowing curves to meet the sea. From A Creachan, behind the Holy Loch, however, over Ardgoil estate, right on to Ben Vorlich, the ranges are altogether different. Rough and gnarled, with jagged and serrated peaks, they form an ideal background to one of the finest views in Scotland. The explanation of this striking contrast is not difficult. The rocks in the foreground are comparatively soft, and therefore weather with rounded outlines. Behind them there runs from south-west to north-east a band of tough, pebbly grits, which, by their weathering, give rise to the imposing outlines of Argyll's Bowling Green and the "Alps of Arrochar." The district is also traversed by numerous lines along which considerable crushing has taken place. The broken rock is entirely removed by weathering, and the resulting features add largely to the tumbled, rugged appearance of this area. The old Highland plateau mentioned in the section dealing with Dumgoyn can be splendidly seen from the high ground behind Greenock or Gourock. Sir Archibald Geikie, in the "Scenery of Scotland," recommends the hills behind Greenock as one of the best spots from which to obtain a good view of the Highlands. A glance at figs. 2 and 3 shows that a ruler could almost be laid right along the tops of the mountains.

In fig. 4 Arran is shown on exactly the same scale as is used in figs. 2 and 3. Its insignificant size is, of course, due to its much greater distance. In the foreground the Island of Bute is seen. Looking at its true proportions (the vertical scale is the same as the horizontal) it is not difficult to understand how at one time the glaciers from the gathering-grounds

Digitized by Google



Highlands behind Loch Long and Kilcreggan.

Highlands from Kilcreggan to Rosneath.

Digitized by Google

Digitized by Google

in the north flowed completely over Bute. The drawing is interesting as showing the marked contrast between the view of Arran obtained from this point and the much more familiar one as one approaches the island from the east. With the latter view in the mind's eye, the distance of Holy Island from Goatfell is rather surprising. Owing to the greater distance of Goatfell from the point of observation, it is dwarfed both in height and bulk by the main peak of the Castles. Although the serrated skyline at Cir Mhor seems quite continuous, the peaks between the notches there are really at very different distances from the eye.

Highlands from Glasgow.

As was to be expected, the atmospheric difficulties were very considerable in surveying distant hills from a city so smoky as Glasgow. Repeated expeditions during a period of nine months were made to the two observation stations without success until two or three successive days in May of exceptionally clear weather, and with the wind in the right direction, enabled us to secure the necessary readings. At first we used a prismatic compass for this survey, and, although this gave a result over the range accurate within one degree, we felt that enough reliance could not be placed on these readings, and so discarded them completely and took the angles as before with the theodolite. The first diagram on each plate shows the whole range on a small scale; the second diagram shows an enlarged view of the most interesting part of the range.

We selected Ruchill Park and Springburn Park as the best points from which to take observations. The highest part of the former is an artificial hillock, known locally as the "Mound" or "Spion Kop," from which a very fine view can be obtained on a clear day. There is a corresponding hillock in Springburn Park, but the view from it is intercepted by buildings, and until it is raised several feet it is worse than useless as an observation point, for it draws people from the place where an uninterrupted view may be obtained. The point from which our drawings were made is beside the reading room, and on a stretch of grass between it and the road. The Highland peaks

Digitized by Google

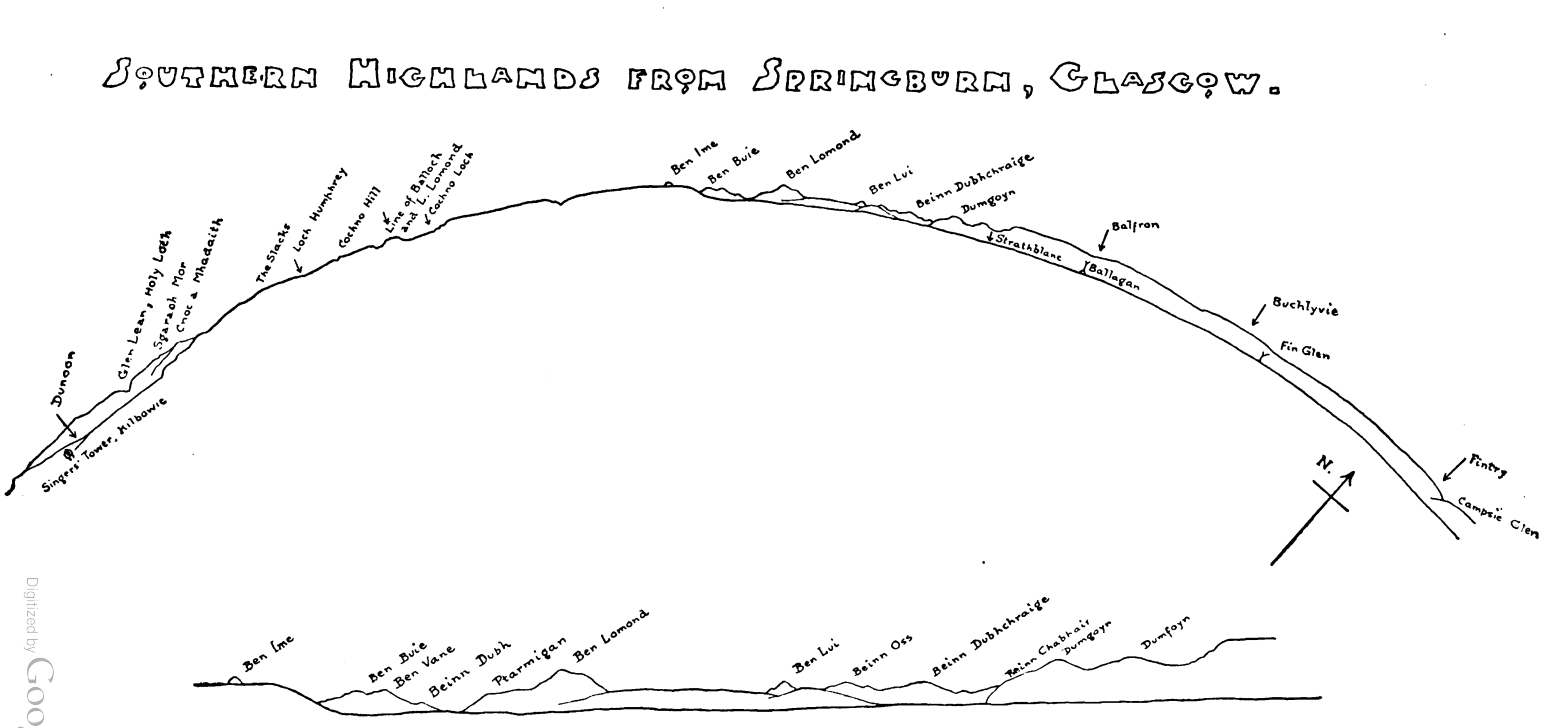
that can be seen from this point are shown in the following table, with their heights and angular distances from Dumgoyn, which stands out conspicuously at the end of the Campsie Hills:—

MOUNTAINS SEEN FROM SPRINGBURN.

Mountain.	Height.	Angular distance from Dumgoyn.
Beinn Chabhair,	3053 feet	1° 32′
Beinn Dubh-chraige,	3204 ,,	2° 41′
Beinn Oss,	3374 ,,	4° 18′
Ben Lui,	3708 ,,	5° 29′
Ben Lomond,	3192 ,,	9° 58′
Ptarmigan,	2398 ,,	11° 31′
Beinn Dubh,	2509 ,,	12° 44′
Ben Vane,	3004 ,,	13° 32′
Ben Buie,	3106 ,,	14° 1′
Ben Ime,	3318 ,,	16° 24′
Cnoc a Mhadaith,	1535 ,,	45° 46′
Sgarach Mor,	1972 ,,	47° 16′

We are enabled to see several interesting Highland peaks from Glasgow, because there is, fortunately, a gap in the line of volcanic hills to the north-west. The Campsie Fells and Kilpatrick Hills were doubtless originally one continuous range, but a great notch has been cut into them, and this gap is now known as the Blane Valley. The stream that runs in this valley at the present time, the Blane Water, is a tributary of the Endrick flowing west into Loch Lomond, and seems far too insignificant to have cut the great opening that one looks through from Glasgow. The explanation of the discrepancy is given in Cadell's classic paper on the Dumbartonshire Highlands, published in the *Scottish Geographical Magazine* in 1886. The valley was probably originally the outflow of the drainage from the district west of Loch Lomond before that loch came into existence. Its river was of considerable size, and flowed eastwards towards the Forth. After the water supply was cut off by the formation of Loch Lomond, a small stream originated in the valley with a flow in a direction opposite to that of the first river. This stream is the Blane Water, a tiny rivulet that seems almost lost in its large valley.

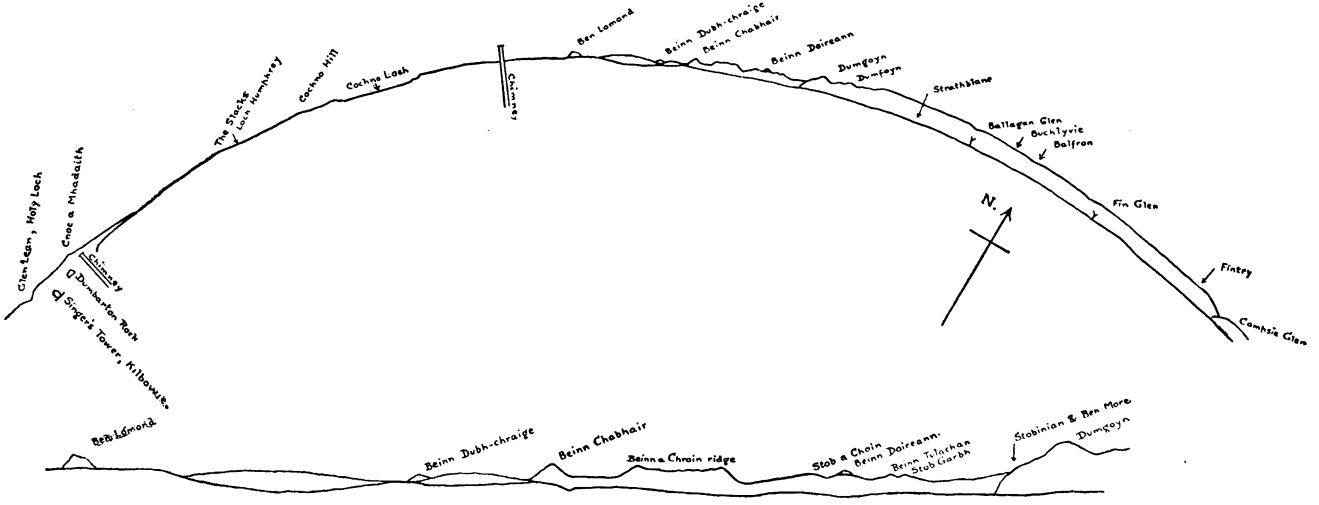
Digitized by Google



Mountains seen from Springburn.

Digitized by Google

Southern Highlands from Ruchill Park, Glasgow.



Mountains seen from Ruchill.

Digitized by Google

As one walks up the short hill towards the gate of Springburn Park a fine conical peak is visible at the edge of Dumgoyn, but on entering the park the view of it is just cut off. This is Beinn Chabhair, which is well seen from Ruchill. Of the Highland peaks visible from this point the most distant is Ben Lui, 39¼ miles off in a straight line. Ben Lomond is 24¾ miles away, and Dumgoyn 9¼ miles.

We have shown the Kilpatrick Hills and the Campsie Fells in both drawings, although they cannot be classed as Highland. Both ranges present some interesting points. They are remnants of the great lava plateau, the material of which gushed from hundreds of volcanoes in early Carboniferous times, and stretched from Stirling to Campbeltown. They are built up in layers, each bed representing a distinct eruption, and this can be very well seen from both Glasgow stations. At Cochno Loch, or to the right of Dumgoyn, a series of steps can be clearly recognised, each step being a different lava flow. It was this phenomenon that gave the name "trap" to these rocks, from the Swedish "trappa"—a stair. A look at the Spout of Ballagan through a field-glass is worth while. There are visible here the sedimentary rocks that underlie the volcanic lavas. To the extreme left of the Kilpatricks the Highland chain is seen again at Cnoc a Mhadaith, behind Kilmun, and, still farther, the deep notch of Glen Lean.

Mountains Seen from Ruchill.

The peaks visible from Ruchill Park are shown in the following table:—

Mountain.	Height.	Angular distance from Dumgoyn.
Stob Garbh,	3143 feet	2° 52′
Beinn Tulachan,	3099 ,,	3° 3′
Cruach Ardran,	3477 ,,	3° 40′
Beinn Doireann,	3523 ,,	3° 51′
Stob a Choin,	2839 ,,	4° 25′
Beinn a Chroin,	3101 ,,	6° 6′
Beinn Chabhair,	3053 ,,	8° 58′
Beinn Dubh-chraige,	3204 ,,	11° 20′
Ben Lomond,	3192 ,,	17° 17′
Cnoc a Mhadaith,	1535 ,,	55° 20′

Digitized by Google

A glance at the two drawings will show the considerable change in the peaks to be seen, made by the seemingly slight shift of the point of view from Springburn to Ruchill. On the extreme right the distant range is seen to be rising into a mountain which is just cut off by Dumgoyn. If the valley had been a very little wider at this point we should have seen Stobinian and Ben More. Cruach Ardran is not named on the drawing, but it may be seen just to the right of Beinn Doireann. The most distant peak visible from Ruchill is Beinn Doireann, 47 miles from Glasgow in a straight line.

Places of interest that lie behind any of the hills shown, but are not themselves visible, have been indicated by arrows pointing downward.

The illustrations in half-tone were made from photographs taken on the hill behind Gourock. They give the panorama from Kirn to Helensburgh, and show the same hills as are represented in the drawings from Gourock. In the first photograph the deep cleft of Glen Lean can be well seen, and on the right the Holy Loch continued up into Glen Massan. Strone Point occupies the middle of the second photograph, and on the right Glen Finart can be made out. This glen cuts completely across the hills to Loch Eck, and it is probable that Loch Eck at one time drained down this glen. The background of the third photograph is occupied by the fine range of the Arrochar Alps, although the scale is too small to be satisfactory. In the fourth illustration the most interesting point is the distinct feature made on the low range in the foreground by the great Highland fault.

Digitized by Google

No. VI.—Notes on a Series of Specimens illustrating the Effects of Differential Weathering on some Scottish Metamorphic Rocks.

By G. W. Tyrrell, A.R.C.Sc., Assistant in Geology, Glasgow University.

[Read 8th November, 1906.]

List of Specimens exhibited.

1. Loch Tay Limestone, 1 mile west of Crianlarich.
2. Limestone with Actinolite, Glen Elg.
3. Limestone, Glen Tilt.
4. Junction of Limestone and Gneiss, Gilbert's Bridge, Glen Tilt.
5. Quartz veins, in folded Gneiss, Gaick Forest, Inverness.
6. Compact Limestone, showing irregular weathering.
7. Cordierite-Actinolite Schist, Dubh Visge, Garabal Hill.

Many of the specimens have a banded appearance, with sharp, salient, more or less parallel ribs on the weathered surface, due to the differential weathering of alternations of harder and softer layers. In 1, flakes of mica are distributed through the more resistant layers. On weathering, these stand out as sharp, parallel ribs, an appearance characteristic of the Loch Tay and other Scottish metamorphic limestones. In 3, the alternations are layers varying slightly in degree of purity. In 2, 4, and 5, bands of actinolite, gneiss, and quartz constitute the harder layers.

No. 7 is a specimen of a peculiar schist found as a block in the bed of the Dubh Visge, a burn near the Garabal Hill igneous complex. Its weathered surface shows large nodular lumps, often an inch across, separated by deep indented depressions. A thin slice shows that the rock consists mainly of biotite and cordierite, the latter being quite fresh, with the characteristic trillings and yellow pleochroic halos. A few crystals of actinolite break across the foliation of the rock. Sillimanite, apatite, and iron ores occur as inclusions in the cordierite. A section across one of the nodules, however, shows an almost total absence of biotite, whose place is taken by tough matted aggregates of actinolite. It is therefore sug-

Digitized by Google

gested that the irregular distribution of biotite and actinolite is the cause of the differential weathering shown by the specimen.

The rock is undoubtedly a Dalradian schist metamorphosed by the Garabal Hill igneous intrusion. It is probably allied to a rock described by Messrs. Dakyns and Teall in their paper on the rocks of Garabal Hill.* They ascribe the nodular appearance to the differential weathering of "patches of felspar about the size of a pea, which weather out as roundish lumps, and give the rock somewhat of the appearance of a pebbly grit."

This is not the explanation of the nodular weathering of the rock here described, for it contains no felspar. The nodules are much larger than those on Messrs. Dakyns' and Teall's specimen. Moreover, the latter came from the slopes of Ben Daimhaim, on the north side of the intrusion, whereas the rock here described came from the south side.

* Q.J.G.S., xlviii. (1892), p. 104.

Digitized by Google

No. VII.—Notes on the Mineral Seams round Airdrie and their Fossils. By Robt. Dunlop.

[Read 14th March, 1907.]

The organic remains found in the Coal-bearing or Carboniferous beds round Airdrie would lead us to infer that the strata were all laid down in fresh water. I have discovered only one place, 1 inch in thickness, between the Kiltongue and Virtuewell Coals, where truly marine fossils have been found. These were Aviculopecten papyraces and Orthoceratites. The fossils were shown to this Society (see page 342, vol. viii., T.G.S.G.).

This is not the only marine bed found in the upper seams of Lanarkshire, similar beds being discovered by R. White, Skipsey, nearer Glasgow,* and at Dalmellington, Ayrshire, by Mr. John Smith; in Fifeshire, by Mr. Kirkby; and also in England. In the Airdrie beds we have animals represented from the class Annelida to the class Amphibia. We have no living representatives of several of these forms. Many of them never made their appearance in geological time after the Carboniferous period; some forms appear in other periods and disappear in geological time, while other forms appear in Carboniferous time and at the present day.

The climate during the laying down of the Carboniferous beds around Airdrie must have been similar to that in many parts of Africa, for in the Palacecraig ironstone no fewer than five genera of Amphibians have been found which were new to science.

Some forty-two years ago Mr. James Russell, of Chapelhall,† found the first of these. He took it up to London and showed it to Professor Huxley, who got the Government to give him £150 for it. It was described by him and named Anthracosaurus Russelli. This specimen is in the museum of the School of Mines, London, and the others are in the collection of the late James Thomson, Esq., F.G.S., and are now in the Kilmarnock Museum. It is thought by some geologists that these animals were related in their habits to the crocodiles of the Nile. The other evidence of the African type is the

* Vol. ii., part 1, p. 52, T.G.S.G.

† See Q.J.G.S., vol. xix., page 56.

Digitized by Google

amount of scorpion skins that may be washed out of the weathered shale in the district and the almost complete scorpion found by me twenty-two years ago.

I will now give a short description of the seams and their most interesting remains found in the various beds round Airdrie in descending order.

The first or highest bed in this district is the Palacecraig ironstone, which is comparatively local, but found also at Quarter. This ironstone was almost all worked out when I came to the district, but, on visiting the pit on the Saturday, one of the workmen told me the place was very much frequented by geologists from Glasgow, and a red-headed one, who appeared to be more enthusiastic than the others, was out almost every Saturday, wet or dry. He said he must have carried away tons. I learned afterwards that this was no other than our own late James Thomson. Of all the seams round Airdrie, this is perhaps the most interesting, for in it Russell found his Anthracosaurus, and between Palacecraig and Quarter no less than five genera of Amphibians have been found. This ironstone was discovered by Mr. David Mushet, manager of Calder Iron Works, about the year 1805. He found it cropping out in a small burn on the west side of Coatdyke; from this section he made his first experiments. In the raw state it contained 35 per cent. of iron, when calcined 70 per cent. At Palacecraig it was 2 feet 6 inches thick, and 30 fathoms below the new red sandstone. The fossils were mostly found near the top of the formation.

The next is what is known as the Upper Coal Seam, and is the highest workable coal on the Scotch Carboniferous system. It attained its greatest development at collieries that were worked to the south-east of Glasgow, where it was 4½ to 5 feet in thickness and of good quality. In the Airdrie district it was never of much account; it was not worked in my day. A section I saw at Whiterigg showed it to be 2 feet 3 inches thick. I found no fossils in this position.

The Ell is the next workable seam, and is 100 feet below the Upper Coal Seam. This coal extends over a considerable area, and has been extensively worked. It was a hard, splinty coal north of Airdrie, but south of it, it becomes a free, soft

Digitized by Google

coal well suited for household purposes. In section—coal, 1 foot 8 inches; sandy shale, 11 inches; coal, 1 foot 7 inches; in some of the weathered sections the sandy shale between the coals contained spores and scorpion skins.

85 feet below the Ell is the Pyotshaw and Main Coal; it is sometimes called the 9 feet coal. They are usually found in contact, forming one seam, the junction of which is indicated by a few inches of coally shale entirely composed of several species of sigillaria in a good state of preservation (generally sigillaria scutellata), at other places this parting may be 35 feet in thickness. Where the two seams are worked separately in some parts round Airdrie this coal has been subjected to the influence of the great intrusive sheet of whin, which extends over the central part of the district, and there the coal is blind. 48 feet below the 9 feet coal we find the Humph Coal Seam, this was one of the first coals wrought in the district and was much sought after as a smithy coal. In section—coal inferior, 8 inches, parting 3 inches; coal good, 2 feet.

This coal was all worked out before I came to the district. I have no fossils from it.

The Splint Seam, which lies 30 feet below the Humph, was all worked out round Airdrie when I came to it in 1868, but near Coatbridge and other parts it was being worked; the coal being of a hard and splinty nature was the furnace coal of Scotland, and for which it has been almost exclusively used round Coatbridge. In the Airdrie district it was almost all converted into a steam coal by the intrusive whin, and from the fossils I have seen in the cabinets of local collectors the roof of the coal must have been very rich in fish remains, the most common being Gyracanthus formosus and Ctenacanthus hybodoides. In the roof of this same coal at Kirkwood, near Coatbridge, I got Orthocanthus cylindrecus (Agas.), two shells Anthracomya modiolarie and Anthracoptera quadrata. These fishes and shells would appear to have had a very limited range, being seldom if ever seen beyond the region of the Splint Coal.

12 feet below the Splint we find the Virgin Coal (locally known as the Sour Milk Coal); it was 1 foot 6 inches thick and was never wrought to any great extent in the Airdrie

Digitized by Google

district; west of Coatbridge it is a good house coal 2½ feet thick. During the cutting, near Airdrie, of the new Caledonian Railway, near Cairnhill they went through the position of this coal showing some of the old workings, and in the shale below it I found some very fine fossils, such as Lepidodendron Sternbergii (Brong.) and Rhacophyllum, all very well preserved.

The next is the Musselband Coal Seam, 42 feet below the Virgin Coal. This seam is very irregular in occurrence and in many places is quite unworkable, being thin and not of good quality. The places where it has been most worked and where it attains its greatest development is at Dykehead and Drumshangie. This coal was sometimes used in gasworks; it gave 11,000 cubic feet of gas per ton, with an illuminating power of 16 candles. In section—coal splinty, 2 feet 2 inches; dark blaes, 11 inches; coal free, 1 foot; 4 feet above this coal was a Musselband ironstone 4 inches thick; I got no fossils from this seam.

Blackband Ironstone.—This lies 27 feet below Musselband Coal Seam, and was also discovered by David Mushet shortly after he discovered the Palacecraig ironstone, and although discovered in the beginning of the century it was not till after the discovery of the hot blast by Mr. Neilson, in 1828, that it was worked to any extent. This seam may be said to have its greatest development between Airdrie and Greengairs, where it crops out; south-west of Airdrie it occurs as a foul coal about 12 inches thick. This seam is rich both in flora and fauna. In plants some rare Lepidostrobuses have been described by Bennie. It was in this ironstone Dr. Grossart, of Shotts, discovered a Macraurus decopod crustacean named Anthrapalæmon Grossartii (Salter), and another Beyrichia arcuata, which ranges from this seam to the slaty band; in shells the Dimyaria are represented by Anthracosia centralis, A. ovalis, and A. phaseola; in fishes it was most prolific, but they were found in detached fragments consisting of teeth, scales, vertebræ, and other hard parts of their skeleton; only in a few instances have any considerable portion of these fishes been preserved. The smaller ganoid fishes, such as Palæoniscus, are exceptions. They have been met with nearly complete.

5 feet below the Blackband ironstone lies the Softband

Digitized by Google

ironstone. It is of a very limited area, and confined exclusively to a strip extending from Airdrie to Greengairs, and at no part is it more than 600 feet broad. The seam was about 20 inches thick, tapering down towards the edge to an inch or two, and finally disappearing altogether. This formation must have been the result of a long narrow lake before the formations above were laid down. Behind Greengairs it passes into an irony oil shale, containing about 18 gallons of oil to the ton, not of a very good quality. In this shale is to be found the carapaces of Anthrapalæmon Grossartii, very plentiful and in a good state of preservation; two complete specimens have also been got; an undescribed specimen of a Prestwichia, and the tooth of Archichthys sulcidens, a figure of which is to be found in Ure's "History of Rutherglen and East Kilbride," a tooth that is very rare.

68 feet below the Softband ironstone we come to the Virtuewell Coal Seam; it gets its name from the fact that a well in a glen north of Airdrie was called the Virtuewell. This coal cropped out beside it, and from this got the name of the Virtuewell Coal; in the eastern part of the district this coal is known as the Johnston Coal Seam, where it has a seam of oil shale above it about 8 inches thick, and was worked for making oil and for gas-making purposes. In this shale I got an almost complete head of Ctenodus cristatus. Where this coal crops out and is weathered, by washing it, some very fine coal spores can be got.

The next in descending order is the Lady Grange Coal, 42 feet below the Virtuewell. Near Airdrie this seam is thin and of poor quality and has not been worked to any extent, only about 12 or 13 inches thick, but east from Airdrie it gets thicker and improves in quality, being 2½ feet. Near Longriggend in the roof of this coal some very good plants have been got. 50 feet below the Lady Grange we get Musselband ironstone and shale. In section—shale, 8 inches; Musselband ironstone, 7 inches; mussel bed, 2 inches; Clayband ironstone, 3 inches; blaes, 4 inches; coal, 6 inches; floor fireclay.

This shale was used for oil making, and produced 30 gallons of crude oil per ton. Various attempts have been made to utilise this ironstone, but it contained a large proportion of

Digitized by Google

phosphorus, which is a most objectionable ingredient in any ironstone. It is from the mussel bed containing the mussels or shells that this seam gets its name. The shells comprising this seam are Anthracosia robusta and Anthracosia acuta. The coal was fairly good. I got also in this shale a tooth of Archichthys sulcidens.

The Kiltongue Coal Seam lies 30 feet below the Musselband ironstone, and varies greatly in different parts of the field, in some parts being 4 to 6 feet thick, and at others only 30 inches, with a parting of about 6 inches between them, sometimes. The thin seam contains 3 inches of cannel coal, being very rich in gas-producing and illuminating powers. The roof of this coal was more productive of plant remains than all the other coals. In the roof of this seam I got the genus Eurypterus, being the highest point recorded in geological strata. 20 feet below the Kiltongue Coal is the Lime-coal Seam that was worked at Glentore. It was 20 inches thick, and was entirely local. This is the only place I know of its being worked.

The Upper Drumgray Coal Seam lies 20 feet below the Lime-coal, deriving its name from the lands of Drumgray, on which it was discovered and first wrought. It ranges from 20 to 30 inches in thickness. It is of different qualities in different parts of the district. In the western it has 40 per cent. of volatile matter; in the east only about 20 per cent. This is due to a great intrusive sheet of basalt, and which is the cause of such good steam coals round Airdrie. It was while sinking a pit near Longriggend, and when they were nearing this coal, I found the remains of a nearly perfect fossil scorpion in 1887 (1st May).

The occurrence of terrestrial air-breathing animals preserved in a fossil state has given to such organisms a special interest in the eye of the geologist, not only as marking the probable position of the land surfaces, but also as giving us some slight indication of the climatal and zoological conditions of the earth at that period. Some very good plants have been got near this coal.

The next is the Lower Drumgray, which lies about 80 feet below the Upper Drumgray, and in thickness it varies from 9 inches to 20 inches. It occurs as a long narrow strip on the

Digitized by Google

south, and extends over the south-eastern part of the district. In some parts it is nearer the whin than the one above it, and is almost into an anthracite. It has had a fair demand as a steam and house coal. Some very good and rare plants have been got in the shales above this coal.

240 feet below the Lower Drumgray we get the Slatyband ironstone. In that 240 feet there are a few seams of coal from 4 to 12 inches in thickness, but none of them is of any economic value. The quality of this ironstone is very good, but it varies in thickness, sometimes very rapidly in a short distance. It generally occurs in troughs or hollows in the floor of the seam, and is sometimes from 2 to 3 feet thick, while beyond these ridges it may not exceed as many inches. Analyses show it to contain about 42 per cent. of metallic iron. This ironstone would appear to have been laid down in a stagnant pool, in which was abundance of confervoid-looking plants resembling the recent conqugatea, but no appearance of joints or cell divisions have been detected in the filaments. In the macaceous sandy shale of this ironstone a plant called cordaites is very plentiful. In certain structural points it approaches closely to the Coniferæ; in other respects to the Cycada. The leaves of this plant are very plentiful, but the stems are very rare. About 720 feet below the Slatyband ironstone we get the Glenboig fireclay seam, which is in the Millstone Grit series, but, not being very prolific in fossils, it did not get the same attention; but, now that the Geological Survey has discovered fossils in it, it may claim more of our attention by and by.

In conclusion, I have to thank most of the colliery managers who were round Airdrie from 1870 to 1898 for information freely given, part of which was embodied in a paper on this subject published by me in 1890 in "Macarthur's New Monkland Parish: Its History, Industries, and People."

PLANTS SPHENOPTEREDEÆ.

Sphenopteris obusiloba.	Brongt.	Kiltongue.	Blaes between Kiltongue and Drumgray Virgin coal, Ladygrange.
,, *nummularia.*	Gutbier.	Kiltongue.	
,, *Schillingsii.*	Andræ.	,,	

Digitized by Google

Sphenopteris latifolia. Brongt. Kiltongue.
,, *rotundifolia.* Andræ. Between Kiltongue and Drumgray.
,, *furcata.* Brongt. Kiltongue and Virgin.
,, *Sternbergii.* Ett. Kiltongue and Virgin.
Renaultia Schatzlarensis. Stur. Kiltongue.
Urnatopteris tenella. Brongt. Kiltongue, Ladygrange.

PECOPTERIDEÆ.

Marcopteris muricata. Schl. Kiltongue, and between Kiltongue and Drumgray.
,, ,, *var. nervasa.* Brongt. Between Kiltongue and Drumgray.

ALETHOPTERIDEÆ.

Alethopteris lonchitica. Schl. Kiltongue, between Kiltongue and Drumgray.
,, *decurrens.* Artis. Kiltongue, Ladygrange.

NEUROPTERIDEÆ.

Neuropteris heterophylla. Brongt. Kiltongue, Virgin, Drumgray.
,, *gigantea.* Sternb. Kiltongue, Ladygrange.
,, *acuminata.* Schl. Kiltongue, Drumgray.

FILICACEÆ INCERTÆ SEDIS.

Rhacophyllum? Brongt. Virgin coal.

CALAMARIEÆ—GROUP I. CALAMITINA.

Calamites varians. Sternb. Upper Drumgray.

CALAMITES II.—EUCALAMITES.

Calamites ramosus. Artis. Kiltongue, between Kiltongue, Drumgray, Ladygrange.

GROUP III.—STYLOCALMITES.

Calamites Suckowii. Brongt. Kiltongue, Lower Drumgray, Upper Drumgray.
,, *cistii.* Brongt. Kiltongue, Lower Drumgray.
Calamocladus equisetiformis. Schl. Kiltongue, between Kiltongue and Drumgray.
,, *longifolius.* Sternb. Kiltongue, Drumgray (Upper).
,, *grandis.* Sternb. Kiltongue.
Palæostachya gracillima. Weiss. Kiltongue, Lower Drumgray, Virtuewell.
Annularia radiata. Brongt. Kiltongue, Drumgray (Upper and Lower).
,, *patens.* Sauveur. Kiltongue.

SPHENOPHYLLEÆ.

Sphenophyllum cuneifolium. Sternb. Kiltongue, between Kiltongue and Drumgray.

LYCOPODIACEÆ.

Lepidodendron ophiurus. Brongt. Virgin.
,, *lycopodioides.* Sternb. Lower Drumgray.

Digitized by Google

Lepidodendron Landsburgii. Kidston. Lower Drumgray.
,, *aculeatum.* Sternb. Humph, Kiltongue.
,, *obovatum.* Kiltongue Blackband Ironstone.
,, *Gaudryi.* Renault. Kiltongue.
,, *serpentigerum.* Konig. Slatyband Ironstone.
,, *rimosum.* Sternb. Lower Drumgray.
,, *rimosum.* Lower Drumgray.
Lepidostrobus variabilis. L. & H. Kiltongue Blackband Ironstone, Palacecraig Ironstone, Slatyband Ironstone.
,, *dubius.* Benney. Palacecraig Ironstone.
,, *tenuis.* Benney. ,,
,, *Russellianis.* Benney. ,,
Lepidophyllum lanceolatum. L. & H. Between Kiltongue and Drumgray.
,, *intermedium.* L. & H. Kiltongue.
Lepidophloios acerosus. L. & H. Kiltongue, Drumgray (Lower and Upper).
Bothrodendron minutifolium. Boulg. Kiltongue, between Kiltongue and Drumgray.
Sigillaria discophora. Konig. Kiltongue Humph.
,, *scutellata.* Brongt. Between Pyotshaw and Main.
,, *reticulata.* Gopp. ,, ,,
Stagmaria ficoides. Sternb. Kiltongue, Drumgray (Lower and Upper).
,, *reticulata.* Gopp. Between Pyotshaw and Main.

Cordaiteæ.

Cordaites principalis. Germar. Kiltongue and Drumgray.
Cordaianthus Pitcairniæ. L. & H. Kiltongue and Drumgray.
Carpolithus perpusillus. Lesqx. Kiltongue.
Rhabdocarpus elongatus. Kidson. Kiltongue.
Artisia approximata. Brongt. Kiltongue.

Crustacea (Ostracoda).

Beyrichia arcuata. Bean. Blackband, Slaty and Softband Ironstone.
Cypridina radiata. J. & K. Blackband Ironstone.
Cythere (carbonia) Fabulina. J. & K. Blackband Ironstone.

Macrura.

Anthrapalæmon Grossartii. Salter. Black, Soft, Slaty, and Palacecraig Band Ironstone.
,, *sp.* In James Thomson's collection, Palacecraig.

Arachnida.

Eoscorpius Dunlopi. Peach. Above Upper Drumgray.

Lamellibranchiata.

Aviculopecten papyraceus. Goldf. Above Kiltongue.
Anthracomya modiolaris. Sow. Splint.
Anthracoptera quadrata. Sow. Softband Ironstone, Splint.
,, *modiolaris.* Sow. Kiltongue, Palacecraig.

Digitized by Google

Anthracosia robusta. Sow. Musselband Ironstone.
,, *acuta.* Sow. Musselband Ironstone.
,, *Urei.* Flem. Softband Ironstone.
,, *ovalis.* Mart. Softband and Blackband Ironstone.
,, *centralis.* Sow. Blackband.
,, *phaseola.* Sow. Blackband.

CEPHALOPODA.

Orthoceras (like) attenuatum. Flem. Kiltongue.
Goniatites. Kiltongue.

FISHES.

Deplodus gibbosus. Agas. Musselband.
Pleuracanthus Lævissimus. Agas. Blackband, Musselband.
,, *cylindricus.* Agas. Blackband.
,, *robustus.* Davis. Musselband.
Janassa Linguæformis. Atthey. Musselband.
Callopristodus pectinatus. Agas. Palacecraig.
Helodus simplex. Agas. Musselband, Palacecraig Splint.
Pleuroplax Rankinei. Agas. Musselband, Palacecraig Splint.
,, *Attheyi.* Barkas. Musselband, Palacecraig.
Sphenacanthus hybodoides. Egerton. Musselband, Palacecraig Splint.
Gyracanthus formosus. Agas. Palacecraig Splint.
Acanthodes wardi. Egerton. Musselband, Palacecraig.
Megalichthys Hibberti. Agas. Soft and Blackband Palacecraig Splint.
,, *rugosus.* Young. Musselband.
,, *coccolepis.* Young. Palacecraig.
,, *pygmæus.* Traqr. Soft and Musselband.
Rhizodopsis sauroides. Williamson. Musselband.
Strepsodus sauroides. Benney. Palacecraig.
,, *sulcidens.* Atthey. Softband, Musselband.
Coclacanthus lepturas. Newb. Musselband.
Dendroptychius sp. Huxley. Palacecraig.
Ctenodus cristatus. Agassiz. Virtuewell, Musselband, Palacecraig.
Sagenodus inequalis. Owen. Musselband, Blackband, Palacecraig.
Elonichthys Egertoni. Egert. Softband Ironstone (found also in lower coal measure).
Urmemus splendens. Palacecraig (found also in lower coal measure).
Euctonius unilateralis. Parkas. Musselband.

LABYRINTHODONTIA.

Anthracosaurus Russelli. Huxley. Palacecraig.
Loxomma Allmanni. Huxley. Palacecraig.
Pholaderpeton sp. Y. & T. Palacecraig.

55 plants, all of which are in my own cabinet, except 3 from the cabinet of Mr. Peter Jack, 3 *Ostracodo*, 2 *Macrura*, 1 *Arachnida*, 10 *Lamellibranchiata*, 2 *Cephalopoda*, 26 Fishes, only 2 of which are found in Lower measures, 3 *Labyrinthodontia*, all being in my own cabinet, except the *Labyrinthodontia* and a fish or two in Mr. James Thomson's Collection in Kilmarnock.

Digitized by Google

No. VIII.—The Loch Lomond Moraines. By J. Renwick and J. W. Gregory, D.Sc., F.R.S., Professor of Geology in the University of Glasgow.

[Read 14th March, 1907.]

The glacial beds beside the southern end of Loch Lomond contain two deposits of special interest—the low-level shelly boulder clay on the shore of the lake and in the Endrick valley and a series of well-defined moraines. The shelly beds are well known from the admirable paper of Dr. R. L. Jack,* who described them as a deposit of true and typical till, although containing worn and broken fragments of marine shells. He concluded that they are the *moraine profonde* of a large glacier, which had filled up the Loch Lomond fiord and climbed the rising ground between the Leven and the Endrick to a height of 320 feet. Further additions to our knowledge of these deposits on the islands in Loch Lomond and on the south-western shore have been made by Mr. Cunningham Craig.† Further information on these beds has been given by D. Robertson,‡ Adamson,§ Jamieson,‖ and Smith,¶ of whom the last recorded the discovery of the remains of a reindeer in a shell bed below boulder clay at Croftamie, near Drymen.

The moraines of this district may be divided into two groups. There are some low-level moraines of normal composition, which are best seen near the northern end of Loch Lomond; reference to the moraine at this locality has been made, amongst

* Jack, R. L.—"Notes on a Till or Boulder Clay with Broken Shells in the lower valley of the River Endrick, near Loch Lomond, and its relation to certain other Glacial Deposits."—*Trans. Geol. Soc. Glasgow*, vol. v., pt. 1, 1875, pp. 5-25.

† Craig, C.—[Shelly Clays of Loch Lomond]. Mem. Geol. Surv., *Sum. Progr. Geol. Surv. U.K.* for 1899-1900, pp. 165-166. Also [Glacial Deposits on Inch Lonaig]. *Ibid.* for 1900-1901, pp. 138-139.

‡ Robertson, D.—"On Clay Beds of Ross Arden, on the banks of Loch Lomond."—*Proc. Nat. Hist. Soc. Glasgow*, vol. i. (1864), 1868, p. 92.

§ Adamson, J.—"Notice of Marine Deposits on the margin of Loch Lomond."—*Mem. Wern. Soc.*, vol. iv., pt. 2, 1823, pp. 334-338.

‖ Jamieson, T. F.—"On the History of the last Geological changes in Scotland."—*Quart. Journ. Geol. Soc.*, vol. xxi., 1865, pp. 170-172, 202-203.

¶ Smith, J. A.—"Notice of the Horn of a Reindeer (*Cervus tarandus*, Linn.) found in Dumbartonshire."—*Proc. Roy. Phys. Soc. Edin.*, vol. i., pt. 2, 1858, pp. 247-249.

Digitized by Google

others, by Anderson.* There is also a series of kame-like moraines situated at high levels in the valleys on both sides of the southern end of Loch Lomond. These deposits were first described as moraines in a paper read before this Society by the late Dugald Bell in 1891, and published in the *Geological Magazine;* † he therein recorded the existence of a mound or ridge of detritus extending for a considerable distance along the hillside on the northern side of Glen Fruin, and described it as the terminal moraine of a glacier coming down that glen. The existence of a corresponding ridge of sand and gravel on the opposite or southern side of Glen Fruin was subsequently discovered by one of us (J. R.)‡ in 1893; he considered it and some mounds on Helensburgh moor to be the complement of that on the northern or north-eastern side, discovered by Bell, and the whole to be a lateral moraine formed by ice coming down Loch Lomond. This view was also advocated by Mr. John Smith,§ but was opposed by Bell in a note appended to his paper of 1893, and in some "Additional Notes," of which an abstract was published in 1896.‖

The Glen Fruin Moraine.

The moraine is usually low and small in comparison with its length and the size of the glacier by which we believe it was formed. It is best developed on the southern flank of Shantron Hill, where it is a well-marked, simple ridge, usually about 12 to 15 feet high and 30 to 35 feet wide. Its base is broader, and it must have been much higher in the deep, narrow valley of Fruin Water, which has been re-excavated through it.

* Anderson, James—"Evidences of the most recent Glaciers in the Firth of Clyde District."—*Trans. Geol. Soc. Glasgow*, vol. x., pt. 2, 1896, pp. 198-209, pl. iv.

† Bell, Dugald—"On a Glacial Mound in Glen Fruin, Dumbartonshire."—*Geol. Mag.*, Dec. 3, vol. viii., 1891, pp. 415-418, and fig. A fuller paper with the same title was also published in *Trans. Geol. Soc. Glasgow*, vol. ix., pt. 2, 1893, pp. 345-354, pl. xii., xiii.

‡ Renwick, John—"Notes on an excursion to Glen Fruin, with a description of the Moraine on its South Side."—*Trans. Geol. Soc. Glasgow*, vol. x., pt. 1, 1895, pp. 96-104.

§ Smith, John—"The Bell-Renwick Moraine."—*Ardrossan and Saltcoats Herald*, May, 1893.

‖ Bell, Dugald—"Additional Notes on Glen Fruin." (Abstract.)—*Trans. Geol. Soc. Glasgow*, vol. x., pt. 2, 1896, pp. 380-381.

Digitized by Google

The moraine consists mainly of coarse sand, which is often well stratified; it includes some layers of pebbles and many scattered boulders. Its stratification and composition, except for the presence of the boulders, are both kame-like rather than morainic. Its material is very different from the boulder clay of the Midland Valley of Scotland, and it is much sandier than the ordinary Scottish or Swiss moraines. In spite of these characters, we think it is a true moraine; it includes more boulders than a kame, and, though some of its material may have been washed down the hill slopes against its edge, we can conceive of no other agent capable of depositing it than a sheet of ice. The differences between this moraine and those in the lower parts of the Loch Lomond basin are probably due to the fact that it was formed on the edge of a thick glacier, the upper layers of which consisted of clear white ice, containing but little intra-glacial material. The glacier was flowing across a country from which all the loose material available for the formation of lateral moraines had been swept away by the earlier ice. Hence the upper layers of ice in this glacier probably contained little material, and, as this moraine dates from the beginning of the retreat of the ice, the hill slopes beside it were probably washed by heavy rain, which would have carried sand on to the edge of the ice. This moraine, moreover, was laid down on steep hillsides, and, there being much water and free drainage available, the fine slimes would have been washed away, and the moraine left as a ridge of coarse, water-washed sands.

The Loch Lomond moraines deposited at lower levels were, on the other hand, formed where there was no such natural drainage; the mud was deposited with the sand, and they have the normal composition of moraines.

The Course of the Moraine.

In Bell's original sketch map,* the course of the moraine is shown on a straight line for a length of nearly two miles from Shantron Hill towards eastern Helensburgh on a course approximately from S.S.W.½ W. to N.N.E.½ E. Had this been the real course of the moraine, Bell's explanation of its origin from

* *Geol. Mag.*, 1891, p. 417.

Digitized by Google

a glacier coming down Glen Fruin would have been probable. But in his map of 1893* the southern end of the moraine is bent to the south-south-east, so that he showed the concave side open to the east. The eastward trend of the southern side of the moraine is, however, far more marked than was known even at the time of Bell's second paper.

The course of the moraine on the northern side of Glen Fruin was described by Dugald Bell in 1893, and on the southern side of the valley by one of us (J. R.) in 1895. The moraine can be traced from the slopes of Shantron Hill, from the level of about 700 feet, across the main Glen Fruin road at 392 feet, past Inverlauren at 300 feet, and down to the Fruin Water at about 200 feet; it can be followed up the southern bank of the Glen Fruin valley, and across the high road from Helensburgh to Luss at 285 feet, about a furlong west of the junction of the Craigendoran road. Across the deep gorge of the Fruin over the Helensburgh moor it has been so worn down that it has lost its morainic contour, and is represented by a line of sand hummocks, sections of which are exposed in shallow pits on the southern side of the road. The material here consists of stratified sands and loams, with pebbles and boulders of Old Red Sandstone conglomerate, Old Red Sandstone, quartzite, and schist, and it includes one band of loam as finely bedded as a lake deposit. The moraine can be followed south-eastward across the moor, and regains the character of an irregular ridge. It passes (alt. 328 feet) by the south-western corner of the Benuchara wood, and continues eastward along the wood, which is on morainic sand, exposed in the stream beds. It gradually rises up the slopes of Benuchara moor to the level of 600 feet, to the south of Benuchara Castle, where it appears to die out at a slightly lower level than on the opposite slopes of Shantron Hill. It, however, extends sufficiently far to the east to show its relations to the presumed Glen Fruin glacier.

The course of the moraine is, therefore, shaped like a "U," with the two arms projecting eastward on both sides of Glen Fruin, and the curved base pointing up the glen. This fact seems to us conclusive as to the origin of the moraine. Had

* *Trans. Geol. Soc. Glasgow*, vol. ix., pt. 2, p. 353.

Digitized by Google

it been formed by a glacier coming down Glen Fruin the arms would have been lateral moraines, and have projected westward up the valley from the base of the "U," which would have been formed as a terminal moraine, and would have pointed down the valley.

The Intra-morainic and Extra-morainic Contrast.

The course of the moraine clearly shows that the ice to which it was due must have come from the east. This conclusion is supported by a comparison of the ground on both sides of the moraine. It must be remembered that we are dealing with the recession of a valley glacier after the disappearance of an ice sheet that had covered the whole district. Hence the country on both sides of the moraine was glaciated before the formation of these moraines.

Nevertheless, there is a well-marked contrast between the intra-morainic and extra-morainic areas, due to the deposition of morainic material. Standing on the moraine near Inverlauren a striking contrast is noticed between the turf-clad, level slopes to the west, outside the moraine, and the irregular hummocky ground, with its growth of rushes and peat, within it. The predominant soil to the west of the moraine is loam, and to the east it is sand, with peat in the wet hollows.

The contrast in the vegetation is so conspicuous that it can be noticed from the opposite side of Glen Fruin, whence the position of the moraine can be recognised by the sharp boundary between the turf outside the moraine and the rank growth within. The upper part of Glen Fruin shows comparatively little glacially deposited material. Moraines are marked on the Geological Survey map at Strone (alt. 500 feet), near the head of Glen Fruin, but they consist of only a short line of low mounds at the foot of the ridge which separates Glen Fruin from Faslane Bay, in Gareloch. Glen Fruin above the moraine shows little sand and no conspicuous sand hummocks, but all down lower Glen Fruin, within the moraine, the ground is littered with irregular mounds and hills of sand. The most conspicuous of these hills is Dumfin or Fingal's Hill, which rises to the height of 277 feet, or about 140 feet above the

Digitized by Google

adjacent floor of the valley. This hill consists of a heap of bouldery, cannon-shot gravel, and sand. It is, perhaps, a fragment of a moraine which once extended right across the valley, and was connected to a bank of similar material, forming a well-marked terrace on the southern side of the valley near Benuchara Castle, a little below the 300 feet contour. The exposed sections in these beds are poor, and we have seen no large angular boulders in them; their material is more kame-like in composition than that of the well-defined moraine to the west. These Dumfin beds may be the remains of a wide sheet of gravel deposited by water on the edge of the retreating ice. They are obviously part of a ridge that was concentric to the Glen Fruin moraine, and was deposited in a later stage of the retreat of the ice. A well-marked glaciated surface stands near Dumfin inside a gate from the road south of Meikle Dumfin.

East of the Dumfin line there are numerous scattered sand hillocks on the plains beside Loch Lomond; they must be the remains of a sheet of sand deposited by the melting of the glacier. The material was probably laid down by water, so that it is not morainic, but the materials are so similar in character to those of the Glen Fruin moraine that they were probably derived from the same source, though deposited differently.

Erratics.

Erratics have been scattered over the district by the older ice sheet, but they appear to be most numerous on the Loch Lomond side of the Glen Fruin moraines, and this fact also supports the view that the ice came from the east. The largest erratic that we have seen is that at Callendoun, 28 feet across, first described by Dr. R. L. Jack;* it stands beside the first stream crossed by the road from Cross Keys to Highfields, and to the south of the road; its position is marked on the 6-inch Ordnance map. South of Highfields there is another

* For references to the literature regarding this boulder, see D. Bell, *Trans. Geol. Soc. Glasgow*, vol. ix., 1891, p. 345; for a figure and an account of boulders also on the Loch Lomond side of the moraine line near Arden, see D. Bell "On some Boulders near Arden, Loch Lomond." *Ibid.*, vol. viii., pt. 2, 1888, pp. 254-261 and p. 341.

Digitized by Google

large boulder of contorted gneiss near the head of the next stream, which rises south of the road, and passes across the western part of Spittal Wood. The boulder above Arden measures 18 feet 9 inches long by 12 feet broad and 9 feet high. The "Long-Acre Boulder" is 9½ feet by 7 feet 8 inches by 7 feet. Erratics are more numerous on and within the moraine than they are outside it, and are further evidence that the ice came from the east of the moraine and crossed Lower Glen Fruin.

Other Corresponding Moraines.

If the Glen Fruin moraine be due to Loch Lomond ice, then evidence of similar moraine lines might be expected at other localities beside Loch Lomond. Remains of them occur at various localities along the loch. Thus, at Luss there is a shelf along the hillside at the level of about 600 feet above the sea, and upon this shelf are hillocks of sand similar to those of the Glen Fruin moraine; this line of material can be seen around the shoulder of the hill at the southern side of the entrance to Glen Luss. The terrace and its hills of sand may be traced southward along the hill face between Glen Luss and Glen Finlas, descending gradually. There is a well-marked difference between the soil above and below this shelf, as the lower slopes contain more sandy material, like that of the moraine.

At Rowardennan there are horizontal terraces of drift along the hillsides, also at the approximate height of about 600 feet; they are probably due to accumulation along the edge of the glacier at some stage in its retreat.

The most conspicuous of the Loch Lomond moraines are in Glen Falloch and at the promontory at Rudha Ban, 1¾ miles south of the northern end of the lake.* A hard ridge of gneiss there projects into the lake, and its northern face is buried by a thick mass of typical morainic material composed of sandy clay, with many large boulders. This deposit was no doubt

* This Rudha Ban moraine has been referred to by J. Anderson. "Evidences of the most recent Glaciers in the Firth of Clyde district." —*Trans. Geol. Soc. Glasgow*, vol. x., pt. 2, 1896, p. 203.

Digitized by Google

formed as a terminal moraine during the retreat of the valley glacier after it had been greatly reduced in thickness by the melting away of the upper layers of clear ice; hence most of the glacier probably consisted of ice charged with intra-glacial material, which gave rise to a normal valley moraine.

The view that the Glen Fruin moraines were formed by the Loch Lomond glacier rests on the probable assumption that the ice, on escaping from the steep, narrow valley of Loch Lomond, spread over the Lowlands at its southern end. This expansion would have carried the ice eastward up the Endrick Valley, as well as westward into Glen Fruin. Hence it is natural to inquire what traces of corresponding moraines there may be in the valley of the Endrick, on the eastern side of Loch Lomond.

There are many hummocks of drift on the hill slopes to the north of Drymen, such as the mound at Shandon, half a mile north of Drymen, and a little below the level of 300 feet; other mounds which, if morainic, should from their position be connected with Loch Lomond ice, occur at the height of about 500 feet outside the western edge of High Wood, beside the Gartmore Road.

The most interesting moraine in this neighbourhood is that marked on the Geological Survey map (sheet 38) as "Kames Strewn with Blocks of Highland Grit." The line of "Kames" is marked on the map for a length of three miles from the level of 650 feet, at a point $1\frac{3}{4}$ miles west by south from Gualann, to the level of about 300 feet on the road from Drymen to Aberfoyle. The ridge is 30 feet high and 100 feet wide at the base in the section cut through it by the Ward Burn, where the road from Drymen to Gartmore crosses the moraine. In places the moraine is not a distinct ridge, but a platform deposited on the side of the hill; and further east, beside the Aberfoyle road, the moraine is both thicker and broader, and has been worn into a series of irregular hills.

It appeared possible that this ridge might be the eastern lateral moraine of the Loch Lomond glacier, but the evidence in the field is conclusive against this hypothesis.

The ridge can be traced across the valley of the stream flowing northward into Flanders Moss, followed by the railway; it

Digitized by Google

passes north of Kepculloch, where it rises to 300 feet, and continues eastward, skirting the Stirling road. It probably includes the hills marked on the 6-inch map (Stirling Sh. XV.) as Lady Stirling's Knowe (300 feet) and the Cairn of Cashlie. It has been greatly denuded at Buchlyvie, which is situated upon it; further east a detached hill, Cowden Knowes (182 feet), 700 yards north-east of Buchlyvie Church, is a fragment of this old moraine.

We prefer to call this ridge a moraine rather than a kame, for most of it consists of dark clay derived from the shales of the Old Red Sandstone, and it contains many boulders. They are largest in the western part, where they are mainly angular blocks of schistose grit, one of which is 11 feet by 9 feet; further to the east the boulders are smaller, and blocks of Old Red Sandstone become conspicuous. In one group of seventeen boulders in 20 square yards, eleven are schists and six are Old Red Sandstone. Still further east, near the Drymen road, the great majority of the boulders are Old Red Sandstone.

This moraine line agrees in many respects with that of Glen Fruin, and in parts of its course it is of the same height, width, and contour, although it contains more clay. Its crescentic course, with the curve outward to the south-west, shows that the ice which deposited it lay to the north-east. We saw no erratics of rocks from the northern end of Loch Lomond, but only masses of schistose grit and slate, which no doubt came from the continuation of the Aberfoyle Slates and Grits.

This moraine shows, moreover, the same contrast as at Glen Fruin between the ground on either side. The fields to the south-west of the moraine are more level, and of much better soil than the ground to the north, which is often strewn with sand and hillocks, some of which are quite detached from the main moraine.

This moraine is the remnant of the lateral and part of the terminal moraine of a glacier which came down the valley between Ben Lomond, Beinn Uird, Beinn Bhreac, Gualann, and Bad Ochainaich on the west, and the bold cliff above Loch Chon and Loch Ard, which forms the western and southern slopes of the Ben Venue mass, on the north-east.

Between these ridges there is a valley with its floor rising

Digitized by Google

gradually from Flanders Moss to the moors (alt. about 400 feet) west of Gartmore, rising to 683 feet at Elrig, 566 feet at Innis Ard, and thence passing to the east of Ben Lomond to the mountains of Beinn a Choin and Meall Mor, the probable source of the glacier which deposited the Buchlyvie moraine.

Judging from conditions of preservation, this Buchlyvie moraine was probably formed at about the same time as that of Glen Fruin.

The Fruin Water and the Helensburgh Air Gap.

One interesting feature in connection with the Glen Fruin moraine is its relation to the physiography of the district. The upper part of the glen is a flat-floored valley with a wide sheet of level alluvium, in one place half a mile wide and about three miles long. This alluvial plain ends at the chapel of West Kilbride, where the character of the valley suddenly changes. The Fruin Water plunges over a waterfall into a young, deep gorge entrenched on the floor of the older valley. The formation of this deep gorge has breached the Glen Fruin moraine opposite Inverlauren and cut through the ridge of Dumfin, beyond which it widens out on to the broad plains beside Loch Lomond. The fact that both Dumfin and the Inverlauren moraine come down almost to the floor of the valley shows that the whole of the young gorge is not pre-glacial. The Fruin Water has re-excavated its channel through the soft sands which filled it up. Probably the whole of the gorge below West Kilbride has been corroded since the first glaciation of this district, but there appears to have been no extensive denudation of rock since the retreat of the Loch Lomond glacier. The change in the character of the Glen Fruin valley takes place at the height of 350 feet above sea-level. At the height of a little below 300 feet there is an air gap through the southern bank of the Fruin Water above Helensburgh.

When Lower Glen Fruin was blocked by ice at the level of the Inverlauren moraine the Fruin Water would have been dammed back and formed a lake in the upper glen, in which its wide sheet of alluvium was deposited; the drainage from the lake

Digitized by Google

would have escape over the wide air gap above Helensburgh to the Clyde. The lowest point on this divide is at the level of a little below 300 feet at the head of Drumfork Burn, which discharges at Craigendoran.

The coincidence in level of the junction of the old and young valleys of Glen Fruin, the height of the Helensburgh air gap and of the Glen Fruin moraine, shows that these three geographical features were connected. The alluvial plain at the height of 350-450 feet in Upper Glen Fruin, therefore, corresponds to the sheet of alluvium in the Blane Valley, south of Killearn, for that was due to the existence of another glacier lake, formed by the Loch Lomond ice blocking the Endrick Water, which rose till it found an outlet through the Blane Valley into the Kelvin.

Digitized by Google

No. IX.—The Intrusive Dolerites in the Neighbourhood of Glasgow. By Peter Macnair, F.R.S.E., *Hon. Secretary*, Curator of the Natural History Collections in the Glasgow Museums, Lecturer on Mineralogy and Geology in the Glasgow and West of Scotland Technical College, and Examiner in Geology in the University of Aberdeen.

[Read 11th April, 1907.]

I. Introduction.

In the neighbourhood of Glasgow, and throughout the great central valley of Scotland generally, there occur numerous sheets, bosses, and dykes of dolerite, which present many interesting petrological and structural characters. These dolerites were first described by Allport in a paper contributed to the *Quarterly Journal* of the Geological Society in 1874, and have since also been described by Sir A. Geikie, Dr. Teall, Mr. Monckton, and lately by Dr. Falconer. Large areas of these dolerites are exposed in the neighbourhood of Stirling, one of the most conspicuous sheets being that which extends from Abbey Craig through Stirling to Denny, where its outcrop has been shifted by a fault. This sheet is probably connected with that so often repeated in the neighbourhood of Kilsyth; in the latter locality it appears, however, to pass on to a higher horizon. To the east of Glasgow, and occurring partly in the Carboniferous Limestone series and partly in the Millstone Grit and Coal Measures, there can be seen some of the largest masses of these dolerites. They are well exposed in the district round Shotts; smaller bosses come to the surface near Carluke and Wilsontown.

In the immediate vicinity of Glasgow several extensive intrusions of dolerite have invaded the Carboniferous Rocks. They can be seen at the following localities:—Hogganfield, Alexandra Parade, and the Necropolis. The latter intrusion is known to come right down into the centre of the city, the dolerite having been found in many excavations in the vicinity of George Square. A microscopic section from a specimen collected at Miller Street shows that the dolerite of that locality is exactly the same as that of the Necropolis Hill, and it is

Digitized by Google

highly probable that it is but an offshoot of the great mass which stretches eastwards in irregular intrusions to near Gartloch. To the west of Glasgow a large intrusive sheet has invaded the Carboniferous Limestones in the neighbourhood of Paisley and Whiteinch. To the north of Glasgow similar intrusions occur to the east of Milngavie; while several intrusions also occur to the south in the neighbourhood of Cathcart. In Ayrshire extensive areas of similar rocks can be seen at Cumnock, Craigie, and Dundonald Castle.

The intrusive character of these dolerites is especially well shown by the manner in which they have altered the rocks which they have invaded. The shales have been porcellanised, and the sandstones in the vicinity of the intrusion have been hardened and much cracked, while the coals have been converted into a soft structureless substance, and sometimes regularly coked. When less altered the coal has been converted into a substance having all the properties of anthracite.

The late Mr. Arthur Pratt accumulated a large number of micro-sections of these dolerites, which were presented some years ago to Kelvingrove Museum, and in going over this collection I have noted a number of new and interesting points that I thought might be worth while bringing before the Society, more especially as, with the exception of a paper recently contributed by Mr. F. Mort, but little attention has recently been paid to these rocks by members of the Society.

The object of this paper, then, is to describe the principal structural and petrographical features of these rocks. For the first purpose a particular intrusion will be selected as a type, and described in some detail. The petrographical characters will then be described, and a short account of the different mineral constituents of the dolerite given. Finally, a number of rock types from the neighbourhood of Glasgow will be described.

II. The Paisley and Whiteinch Intrusion.

Perhaps the best sections which we know showing the manner in which these sills penetrate and alter the sedimentary rocks they come in contact with are those seen along the margin of

Digitized by Google

the extensive sheet which has pierced the Lower Carboniferous Limestones to the west of Glasgow. This sheet extends from Barshaw, east of Paisley, northwards to New Mains, where it is covered by the alluvial deposits of the Clyde. An exposure occurs near Elderslie House, and it has long been known to occur in the channel of the Clyde near this point, where it has caused considerable obstruction to navigation. On the north side of the Clyde the dolerite can be seen at Blawarthill and Bankhead, from which point a long narrow tongue stretches south-eastwards for over a mile, terminating near Whiteinch, where it is exposed in the quarry at the Fossil Grove. A smaller patch of dolerite was quarried for a long time at Seedhills, Paisley, and a bore put down at Saucel, a little to the west of its outcrop, shows that it rests upon a thick bed of sandstone, which passes downwards into a series of alternations of shale and limestone. A fine section showing the relationships between the dolerite and the sedimentary strata can be seen on the south side of the Cart near Blackhall printfield. At this point the dolerite dips towards the south-east at an angle of 20°, and rises into a prominent ridge above the level of the surrounding country. Overlying the dolerite, and also having a dip to the south-east, there can be seen on the south bank of the Cart a section exhibiting about 60 feet of shale, with thin bands of clay ironstone. It is into these shales and ironstones that the dolerite has been intruded. Underlying the dolerite is a band of limestone, known locally as the Blackhall limestone. The position of this bed is shown by a long narrow gully which runs from the banks of the Cart across the Blackhall Road in the direction of Dikebar Hill. This gully is artificial, and marks the position of the limestone outcrop, along which it was worked many years ago.

The contact phenomena seen in the Blackhall section are exceedingly interesting, the line of junction between the dolerite shales and ironstones being well marked, though very irregular. Tongues of dolerite are seen to pass from the main intrusion into the shales, incorporating portions of the sedimentary rocks, which vary in size from the smallest fragments up to large masses measuring several feet in length. Everywhere along the line of junction the shales have been much hardened, and a well-

Digitized by Google

From Photo. by J. W. Reoch.

Fig. 1.—Sill of dolerite, Arklestone cutting, near Paisley.

From Photo. by J. W. Reoch.

Fig. 2.—Limestone, coal, and dolerite, Arklestone cutting, near Paisley.

Digitized by Google

Digitized by Google

marked columnar structure superinduced upon them. At one part of the quarry a large surface of shale lying immediately upon the dolerite has been laid bare, and the ends of the columns are well shown. Near the line of junction a peculiar brecciated structure can be observed. This is probably due to the fracturing of the sedimentary rocks along the line of the intrusion. In another part of the quarry there is a considerable exposure of the dolerite along the line of strike, and at this point the sedimentary rocks appear to have been thrown into a series of small undulations, whose longer axes run with the dip of the strata. The cause of this is not quite apparent, but it seems to be due to the forcing of lenticles of the igneous rock between the bedding planes of the shales and ironstones. In this portion of the quarry, and at a distance of about 6 feet above the line of intrusion, there is a lenticle of limestone about 6 yards long and a foot thick, containing numerous fragments of crinoid stems. The limestone is underlain by shales, which are pierced in all directions by a plexus of thin veins of dolerite, and is perhaps one of the best exposures to be seen in the quarry. I have not observed this limestone in a similar position above the dolerite in any other part of the quarry, nor is it exposed in the section shown along the banks of the Cart, so I have come to the conclusion that it is simply a part of the underlying limestone already mentioned that has been split off and forced upwards.

The sheet of dolerite is about 15 feet thick, and, as usual, is much finer grained (passing into aphanite) along the margins of the sill. A rude, columnar structure passing from the top to the bottom of the sill may be seen in some parts of the quarry. Vesicular structure is well developed along the edges of the sill, but well-marked bands and lines of single vesicles also appear in the centre. The vesicles are usually empty.

The next section which I describe is that seen on the railway cutting near Arklestone on the Glasgow and Paisley Joint Railway. At the north-east end and top of the section occurs the Hurlet Limestone, having a thickness of about 2 feet 3 inches, which is immediately underlaid by about 6 inches of alum shale. Below the shale comes the Hurlet Coal and the dolerite. The dolerite has evidently forced its way along the

Digitized by Google

line of the Hurlet Coal, which has been split in two by the intrusion. Patches of the coal are included within the igneous rock, and the coal is everywhere much altered, showing fine examples of columnar structure. A thin layer of iron pyrites occurs between the coal and the overlying shale.

The columns in the coal are not usually very large, but they are well formed. They are nowhere seen to pass from side to side of the bed or of the smaller bands into which the bed has been split, but usually present a series of little columns rising in tiers above one another, the columns in some of the tiers being inclined to those immediately above and below it. It has already been observed that in several places there occur patches of the coal completely surrounded by the dolerite. In these masses the curvatures of the columns is so arranged that they stand at right angles to the boundary wall of igneous rock. Towards the west end of the cutting a bed of shale is seen to underlie the coal, having a thickness of about 18 feet. It is upon this bed that the dolerite rests, and it has been much altered where it comes in contact with the dolerite. The shale has been bleached to a whitish-blue colour, and is hard and splintry where the dolerite comes in contact with the shale.

The contact phenomena shown at the Arklestone cutting presents much the same features as that seen at Blackhall, and need not be further described. The intrusive sheet has a thickness of about 80 feet, and is much closer grained along the chilled margins than in the centre. Along the centre of the sill the dolerite has weathered much more rapidly than at the edges. This may be accounted for by supposing that the more coarsely crystalline rock is more easily disintegrated than the more compact rock of the edges.

The next section which I describe is that seen in the quarry at the Fossil Grove, Whiteinch. An account of this section by the late Dr. J. Young and Mr. D. C. Glen is given in our *Transactions* in their paper, entitled "Notes on a Section of Carboniferous Strata containing Erect Stems of Fossil Trees and Beds of Intrusive Dolerite in the Old Whinstone Quarry, Victoria Park, Lower Balshagray, near Whiteinch and Partick." Here, as in the two sections already described, the contact of the dolerite with the sedimentary rocks is well shown. An

Digitized by Google

intrusion of dolerite, of which about 15 feet is seen in the quarry, has at this point invaded a series of beds of shale and sandstone belonging to the Lower Carboniferous Limestone series. Near the base of the intrusion two bands of sandstone are incorporated in the igneous rock. Veins and minute strings of white dolerite are seen to penetrate a bed of black shales that overlies the fossil trees, and in some cases the smallest of these veins are seen to enclose minute fragments of the shales. In passing outwards from the centre of these veins to the sides, they are found to become gradually more vitreous in character, and close upon the margin they become densely spherulitic, this densely spherulitic area forming a thin band parallel to the sides of the vein. Following this is a less spherulitic and more glassy band, in which the vitreous material is almost quite colourless. This is succeeded by a sharp but irregular boundary line, and beyond it lies a narrow band of deep brown or coffee-coloured glass. Mr. Rutley is of opinion that this band may have resulted from the fusion of the shale, and that two narrow but different bands of vitreous origin have been developed side by side on each side of the vein. The brown bands represent the fused walls of the shale.

It seems highly probable that the Seedhills, Blackhall, Arkle-stone, and Whiteinch intrusions belong to the same great mass, and are connected with each other below the surface. So far as I have been able to determine, the dolerite at these different exposures does not appear to occupy exactly the same stratigraphical horizon. The probability is that they represent sills shooting out along the lines of bedding from a common plug.

III. Mode of Occurrence and Structure of the Dolerites.

The intrusive dolerites of the Midland Valley are dark-coloured rocks occurring in the form of bosses, sheets, and dykes. The sheets sometimes present laccolitic habit, while the dykes occupy true fissures, having a general east and west trend. That there is a genetic relationship between the dykes and sills seems most highly probable. Their petrographical similarity was first pointed out by Sir A. Geikie in 1896, and

Digitized by Google

the researches that have been made since that time have all tended to confirm the relationship between the two types of intrusions, showing that, if they are not strictly contemporaneous, they at least belong to the same period of igneous activity. The exact age of these intrusions has not yet been finally established. Sir A. Geikie, proceeding upon the assumption that the east and west dykes were of Tertiary age, concluded that the sills belonged to the same period. Within the last few years considerable doubt has arisen regarding the Tertiary age of the east and west dykes, while it has been found possible to establish a late Palæozoic age for many of the sills seen in Fifeshire, which present striking affinities with those found in the west of Scotland.

Having already described in some detail the features of a sill, it is hardly necessary that more should be said regarding their mode of occurrence. It has been shown that the molten material has found its way between the stratification planes, and has there cooled into a solid bed or sheet. These sills vary both in thickness and extent; thus in the quarry at Whiteinch sills of not more than 6 inches have found their way along the bedding planes, they being offshoots from the larger sill, while some of the larger sills must be over 100 feet in thickness.

In some instances these sills are so regularly intercalated between the bedding planes of the sedimentary rocks that they have all the appearances of a contemporaneous lava flow, but a closer inspection will generally show either that the sill crosses from one bed to another or that a certain amount of contact metamorphism has taken place both on the upper and under side of the mass, thus demonstrating its intrusive character.

Many of these sills show a columnar structure more or less perfectly developed, the columns standing at right angles to the cooling surfaces. Reference has already been made to this structure, as seen in the different exposures of the Paisley and Whiteinch intrusion.

It has just been said that the exact age of these sills cannot be determined, as they do not in themselves afford any evidence regarding the period of their intrusion further than that they must be of later age than the rocks into which they have been

Digitized by Google

intruded. Such evidence as is available in the meantime seems to favour the idea that they are of later Palæozoic age. As we know nothing definite about their age, so we also know very little regarding the volcanic phenomena with which they were most likely connected. I have pointed out that the long east and west dykes may be of the same age as the sills, but whether they are the feeders of the sills, or the sills have been supplied from separate and independent plugs, is a point which has not been established.

Much discussion has taken place as to whether these sills of intrusive dolerite have simply pushed aside or actually assimilated a portion of the strata into which they have been injected. Attention was first directed to this question by Mr. C. T. Clough, who studied the problem in connection with the whin sill of Northumberland, and the conclusion which he arrived at forced him to believe that the whin consists in part of altered sedimentary beds, and also that it partly represents beds that at one time were in the position now occupied by the sill, the igneous rock having made room for itself, not by pushing aside these beds, but by assimilating them into itself. In support of this he points out that there is "a general absence of mechanical disturbance of the surrounding beds, that is, the beds end abruptly against the whin without any evidence of disturbance, such as faulting, bending down towards the intrusive mass," &c.

Professor Bonney adversely criticises the conclusions arrived at by Mr. Clough, and advances the theory that when the molten material made its way towards the surface it uplifted the overlying beds into an arch, and, as these were unable to adapt themselves to the tension to which they were subjected, they were cracked and broken into a number of separate blocks, along which the molten basalt found its way. He also points out that these cracks need not in all cases be vertical, and that cracks parallel to the bedding planes would also be produced.

So far as my own observations go, I feel inclined to support the idea that the molten rock entered fissures that had already been opened parallel to the bedding planes of the stratified rocks. It has occurred to me that a plausible explanation of the manner in which these sills have found their way along

Digitized by Google

the bedding planes of the sedimentary rocks is afforded by the supposition that, when the sedimentary rocks were being folded from their original horizontal position into a series of anticlines and synclines, rents or fissures were opened along the bedding planes.

It is not my intention to discuss this interesting question in the present paper, but it may be pointed out that in experiments with the folding of clays, &c., in which it is sought to experimentally demonstrate the processes and results of rock folding, it will be often found that, where a divisional plane occurs between two distinctly marked layers of clay, this plane acts as a line of weakness, and a separation of the two layers takes place, leaving a space which lies parallel with the lines of folding. When the vertical fissures were opened in the crust of the earth the molten rock would first find its way into these from the interior, then the vacant spaces, whose mode of formation has been described, would tap the molten rock at the points where the vertical fissures crossed them. If this view of the origin of these sills be adopted, it seems to me to explain in a satisfactory manner the remarkable persistency with which some of these sills keep to a certain horizon; it also accounts for the apparent absence of any evidence of mechanical displacement in connection with these sills.

It will, of course, be understood that this hypothesis supposes that the molten material must have been introduced into the sedimentary rocks after they had been folded into their present position. As an example of the striking manner in which these sills coincide with the bedding planes of the sedimentary strata, reference may be made to the anticlinal axis, known locally as the "riggin," at Kilsyth. Here the sedimentary rocks of the Carboniferous Limestone series and the intrusive sills form a well-defined arch, which extends from a mile and a half west from Croy to the neighbourhood of Low Banton.

Besides these intrusions of dolerite which take the form of sills or sheets, there are others which appear to occupy true fissures in the crust of the earth, and rise through the strata as vertical walls or dykes. Quite a number of these can be seen in the neighbourhood of Glasgow, and, as their general characters are so well known, they scarcely require any descrip-

Digitized by Google

tion here. As has already been pointed out, they were at one time considered to be of Tertiary age, but it now appears more likely that they belong to a late period in Palæozoic time.

Two well-known intrusions of the dyke type appear to the north of Glasgow at Bishopbriggs. One of them has been traced from Wilderness Plantation, near Hilton, eastwards by Cadder, Mollinsburn, and Slamannan, to the Bathgate Hills near Torphichen. At Mollinsburn this dyke makes a striking feature in the landscape, as it rises like a wall above the sedimentary strata, into which it has been intruded. To the east of Mollinsburn this dyke enters one of the north and south sills of the same character as those described in the preceding part of this paper. I have not been able to determine the exact relationship of the dyke to the sill at this point.

Still further to the east this dyke passes along the northern margin of the extensive sheet, which comes to the surface to the south-east of Slamannan, and in the neighbourhood of Torphichen it passes along the southern margin of a similar sheet. The latter sheet is also traversed still further to the north by two similar dykes.

In speaking of these dykes and sills as seen in the vicinity of Bathgate, Dr. Falconer says, "The similarity in petrographical type of these intrusions indicates contemporaneity of origin in late or post-Carboniferous times. Strict contemporaneity is not, however, implied, the intrusions having evidently been inserted in succession during the period. These intrusions, with a north and south elongation, are probably the oldest, being cut, as in the case of the Raven Craig, by the east and west faults, along which dykes have usually arisen. These dykes are apparently the feeders of the sills, the lowest and the oldest of which are sometimes covered by the feeders of the higher and younger."

A similar dyke to that already described runs in a parallel direction, accompanying the first dyke right across the country at the distance of about a mile further to the south. This dyke can be traced from the north of Possil Loch eastwards by Bishopbriggs, where it is well shown in the railway near Myremailing. It is also exposed at Claddens in a quarry, where it has been worked for road metal. From this point it can be

Digitized by Google

followed eastwards by Auchinloch and Knockmilly, but here the continuity of the dyke appears to be interrupted, as it is not seen at the surface, and when it next appears it is at a considerable distance to the south of its former bearing, near the village of Chryston.

A third mode of occurrence of these intrusive dolerites may now be briefly referred to, namely, such vertical plugs or bosses as we find at Dunglass Hill, near Strathblane. These plugs have all the appearance of having been at one time the site of an ancient volcano, the orifice of which has eventually been filled with a plug of molten rock.

As a result of denudation, these sills, dykes, and bosses of dolerite often present well-marked features in the landscape. Where the sills appear at the surface they give rise to hummocky eminences covered by exposures of naked brown rock in an advanced stage of decomposition. In some cases the sills form well-marked escarpments, due to the weathering away of the underlying sedimentary strata. The mural-like character of some of the dyke intrusions has already been referred to, and need not be again described. The plugs or bosses often form isolated eminences, as Dunglass Hill and others.

All through the Clyde Valley these rocks have a general sameness of petrological character. They may be either finely or coarsely crystalline, basic, augitic, and only occasionally amygdaloidal. It is not quite apparent what the true relationships of these rocks may be to their volcanic representatives. Some petrographers have remarked that the more deeply seated portions of massive flows of basic lava often exhibit a doleritic texture, and it is highly probable that these sills, dykes, and bosses may represent intrusions of lava which have taken place in the lower parts of the volcanic neck.

It has already been pointed out that the central portions of these dykes and sills are much more coarsely grained than the marginal areas, this, of course, being accounted for by the chilling of the edges where they came in contact with the surrounding rock. In the central and more coarsely crystalline portions of the rock the mineral constituents can often be determined with the aid of a pocket lens, when it is usually seen to be composed of a grey or pink felspathic constituent, accom-

Digitized by Google

panied by a dark-green ferro-magnesian constituent, a dark lustrous iron ore, and brassy-looking iron pyrites.

Towards the margins the sills and dykes pass into close-grained and compact dolerites, which are known as aphanites, and in which it is impossible to determine without the aid of the microscope the different mineral constituents. The degree of coarseness seems to be determined to some extent by the thickness of the sill. Some of the very coarse-grained rocks which occur to the north of Glasgow have evidently been developed in sills of more than usual thickness, and in which the cooling of the central parts must have been correspondingly slower, the resultant crystals being much larger.

The most common type of dolerite consists of plagioclase and augite, the greenish colour, which is so common in many of those rocks, being due to the development of a secondary chloritic constituent, replacing the original augite. The term diabase, first introduced in 1813 by Alexander Brongniart, was intended to include rocks composed of felspar and hornblende, and was the same as Hauy's diorite. Diabase is now often used to designate those dolerites which have become more or less chlorotised, while the unaltered type is simply known as dolerite.

It is often the case that the augite of the dolerites is either replaced by or associated with other ferro-magnesian constituents, when the following varieties may be recognised, all of which are shown in the Clyde valley:—

Dolerite, - - - -	Plagioclase + Augite.
Mica Dolerite, - -	Plagioclase + Augite + Brown Mica.
Hornblende Dolerite, -	Plagioclase + Augite + Hornblende.
Hypersthene Dolerite, -	Plagioclase + Augite + Hypersthene.
Olivine Dolerite, - -	Plagioclase + Augite + Olivine.

IV. Minerals of the Dolerites.

Plagioclase.—The plagioclase felspar, which forms an essential constituent of these rocks, usually presents a columnar habit, which is due to the crystals being elongated parallel to the "a" axis, the forms 001 and 010 being about equally developed. The distinguishing character of this mineral is its lamellar or polysynthetic twinning, the most common type

Digitized by Google

being that known as the albite law, in which case the twin striations appear parallel to the brachypinacoid. Examples of twinning, according to the pericline law, are not uncommon. In this type the twin lamellæ cross those of the albite type at right angles. Carlsbad twinning occurs in association with that of the albite type, and this is most probably what Allport refers to when he speaks of certain twins which appear to be orthoclase. In fresh crystals the cleavage is distinctly shown, but is not so apparent in those which have suffered through decomposition. A herring-bone structure, similar to that often seen in augite, can occasionally be observed in the felspar. Stecher considers this structure to be due to a micro-pegmatitic intergrowth of plagioclase and quartz.

Augite.—Augite occurs in more or less well-formed crystals, or in crystalline grains of irregular form. When idiomorphic, sections at right angles to the "c" axis show the following forms:—110, 100, 010; when cut parallel to the "c" axis some of these forms are shown terminated by 111. In specimens from Craigpark and Hogganfield the augite crystals are often seen to be greatly elongated parallel to the "c" axis, and in some cases exhibit peculiar club-shaped crystals, which are probably due to subsequent corrosion. The result of this elongation along the "c" axis is that the augite crystals often present lath-shaped forms, some of which measure 15 mm. in length by 1 mm. in breadth. Crystals showing twinning upon the orthopinacoid are not uncommon; repeated twinning in the same individual has also been observed in a number of instances.

The cleavage, which is parallel to the prism faces, and intersects at an angle of 87° in sections at right angles to the "c" axis, is usually fairly distinct, and is shown by irregular, thick, and sometimes branching cracks. The colour of the augite is generally brown or pale yellow, but in some cases it presents a pale purplish tinge.

In specimens from the Necropolis Hill, Dennistoun, and other localities the augite shows a distinct pleochroism. According to the observations of Allport, the pleochroism of the augite in these rocks is invariably connected with the purplish tinge in its colour, which is often, though not always, diffused through the crystals. It has also been noticed that the amount of

Digitized by Google

pleochroism varies with the depth of the shade. Crystals of augite which have a uniform colour are, however, not nearly so pleochroic as hornblende, and a little experience in the examination of thin sections under the microscope will enable the observer to distinguish one mineral from the other. Between crossed nicols augite exhibits fairly bright chromatic polarisation.

Zonal structure is often present in the augite of these rocks, and in specimens from Hogganfield this is sometimes seen to present the well-known hour-glass structure. In such cases, when the crystal is viewed in a section cut parallel to the clinopinacoid, it appears divided into four parts, those parts which lie opposite each other having a similar optic orientation. The effect of this is to produce a figure having a striking resemblance to an hour-glass. In sections cut parallel to the orthopinacoid, a similar structure may be seen. In sections cut at right angles to the vertical axis the crystal simply shows the usual zonal structure. The manner in which this hour-glass structure has been produced is supposed to be somewhat as follows:—Originally a skeleton crystal of augite has been formed, having the shape of an hour-glass; afterwards the original skeletal part was surrounded and filled in with material which had a somewhat different chemical composition, and consequently bore a different angle of extinction.

The ophitic structure so characteristic of dolerites seems to be comparatively rare amongst the dolerites of this area. A thin section of the sill, which outcrops near Glenboig railway station, shows this structure in a very perfect state of development. In this section the felspar appears to have crystallised out at a slightly earlier period than the augite, and exhibits well-formed, lath-shaped crystals. The augite, on the other hand, has played the rôle of ground mass, and occurs in plates or polysomatic masses, which are allotriomorphic, and which show that they are in crystalline continuity by their behaviour under crossed nicols.

Perhaps the most common habit of the augite in these dolerites, both in the sills and dykes, is the hypidiomorphic granular form. This character is well shown in a thin section from Craigpark, Dennistoun; in this section only a small proportion of the augite crystals show idiomorphic outlines—that

Digitized by Google

is, show evidence of having freely developed their external forms. By far the greatest proportion of the crystals occur as granules without definite crystallographic boundaries. It may not infrequently happen that the same crystal may be partly ophitic and partly idiomorphic.

Reference has already been made to the long columnar habit assumed by the augite crystals towards the centres of the larger sills. Occasionally such crystals show evidence of having been subjected to considerable mechanical deformation, they having been bent into variously curved forms. A section of dolerite from Hogganfield shows one of these long columnar crystals of augite bent into a sigmoidal curve. No actual rupture of the crystal has taken place, but that it has been subjected to considerable strain is shown by anomalous double refraction at certain points when the major part of the crystal is extinguished. Dr. Falconer has observed that the long lath-shaped felspars seldom show evidence of any mechanical deformation, and he concludes that the movement which affected these crystals must have taken place soon after the crystallisation of the augite. As regards the manner in which this movement has taken place, I quote the words of Dr. Falconer—"Most probably the central framework of columnar augites, which may be supposed to have been formed within the igneous magma, was, on reduction of the volume of the mass, unable to withstand the pressure of the overlying rocks, and in consequence collapsed, the individual augites being in many cases bent, shattered, and broken."

Apatite and iron ores are occasionally found enclosed in the augite, magnetite being particularly abundant, and in some instances forms the greater bulk of the crystal. Divitrified material also occurs included in the augite.

The augite of these dolerites have in many cases been altered into chlorite, and all the stages in the process of decomposition may be traced. As a rule, the process of alteration appears to begin from the periphery, and gradually extends inwards, advancing along the cleavage of the augite, until the whole crystal has passed into a bright, green-coloured chlorite.

Hornblende.—Hornblende occurs more or less commonly in all the sills, and I have observed it both in those to the north

Digitized by Google

and south of Glasgow, as, for instance, in sections from the Necropolis intrusion and from the Cathcart intrusion. As will presently be shown, it most frequently occurs in association with augite, and its peculiar association with augite has led some petrographers to consider it simply as a decomposition product from the augite. In other instances no augite kernel is present, and the crystal has all the appearances of being an original constituent of the rock, but to a consideration of this question I shall return presently.

When hornblende occurs without a kernel of augite, it exhibits the usual habit of that mineral, and shows the predominance of the prism faces over those of the pinacoid. The prismatic cleavage is well developed, and in cross-sections of the prism make angles with each other of 124° and 56°. Longitudinal sections show a single set of parallel cleavage cracks, and give extinctions which vary from 0° in sections parallel to the orthopinacoid to 20° in sections parallel to the clinopinacoid. In sections from the 100 and 001 zone the extinction position bisects the angles formed by the cleavage cracks. All these characters, with the exception of the external form, are also present when the hornblende is seen in association with augite. The colour of the hornblende is a deep clove brown, and the pleochroism is as follows:—

α Pale brown.
β Deep brown.
γ Deep brown.

As has already been mentioned, one of the most interesting features of these rocks is the intimate association of hornblende and augite. In most instances the hornblende occurs as a marginal fringe surrounding the augite, and the intergrowth has taken place in such a manner that the plane of symmetry and vertical axis is common to both minerals. In most instances the line of junction between the augite and hornblende is exceedingly irregular, and strings and patches of hornblende are seen to be incorporated in the augite, and flecks of hornblende wholly surrounded by augite are not uncommon. Now, the question arises, is the hornblende to be looked upon as an original constituent of the dolerite formed at the same time as the other mineral constituents, or is it a secondary mineral

Digitized by Google

formed at some period after the consolidation of the dolerite by a paramorphic change of augite?

Dr. H. Teall, after describing a similar association of hornblende and augite seen in the Inchcolm augite-picrite, arrives at the following conclusion:—"The fact that the brown hornblende here referred to shows the definite external form of that mineral at once shows that this is not analagous to 'uralitisation.' Is it, however, a case of what may be called 'amphibolisation'? This appears to be the view of Macpherson, who suggests that the pleochroism of the augite may be due to the intercalation of ultra-microscopic lamallæ of hornblende."

German petrographers seem to favour the view that we have, in this intimate association of hornblende and augite, an undoubted contemporaneous intergrowth of these two minerals, and certain analyses made by Rohrbach of these two minerals from a variety of teschenite seem to confirm this view.

Dr. J. D. Falconer, in a paper recently published dealing with similar rocks seen in the neighbourhood of Linlithgow and Bathgate, is inclined to favour the view that the hornblende is of secondary origin. After giving a description of the mode of occurrence and relationship of the two minerals, which appears to be exactly the same as that found by me in the Glasgow neighbourhood, he admits that much of the evidence may be read in both ways—that is, it may be considered to favour either the one view or the other, according to the leanings of the petrographer who has the minerals under consideration. Dr. Falconer accepts the conclusion laid down by Rosenbusch, that definite discrimination between the two is only possible when the hornblende occurs in its own form or in that of augite; if the external form fails, the discrimination must always remain uncertain. Further, Dr. Falconer says—"In these diabases I have been unable as yet to find any definite primary outlines in the hornblende, and until these are found it is most convenient, especially in view of the occasional occurrence of hornblende with the outlines of augite, to consider the whole of secondary origin."

So far as my own observations go, I feel inclined to favour the view that the hornblende is almost entirely of secondary origin. When the hornblende occurs in association with augite

Digitized by Google

the relationships are such as scarcely to leave any doubt as to the secondary origin of the hornblende, for, though, as has already been pointed out, it exhibits all the physical and optical properties of hornblende, yet the external form, when present, is invariably that of the augite, which it encloses.

The alteration of augite into hornblende was long ago described by G. Rose in crystals first found in the Ural. Subsequently similar crystals were found in the augite porphry of Predazzo in the Tyrol and other localities. From all these localities the crystals exhibited the structure and cleavage of hornblende, but presented the external habit of augite. These pseudomorphs of hornblende after augite were named uralite by Rose after the locality where he first discovered them. The crystals from the Ural were found in an augite porphry, and exhibited all the faces found in common augite, as well as twinning parallel to the orthopinacoid. Though the form of uralite is thus seen to correspond with that of augite, the internal structure is totally different, as the crystals are cleavable only in two planes, which are the same as that seen in hornblende. This pseudomorph appears to be one of the few that possess cleavage. This partial or complete alteration of augite into hornblende by paramorphism or allomorphism is known as uralitisation.

The chemical reaction which has taken place in the alteration of augite into hornblende is most simply accounted for by the substitution of magnesia for lime. It has been observed in crystals from Avendal that in certain cases, where the hornblende is seen to completely envelop the augite, they are filled inside with ferruginous calcite, which readily effervesces with acids. This occurrence gives support to the idea that the lime has been removed as carbonate. It seems most likely, then, that this alteration has taken place by the percolation of water through the dolerite. This process of alteration has been facilitated by the occurrence of fissures and cracks in the augite. The general appearances presented by the association of these two minerals which have already been described seem to favour this as the most likely process which has taken place in the conversion of the augite into hornblende.

Reference has already been made to the occurrence in the

Digitized by Google

same slide of crystals of hornblende presenting all the features just described with others which exhibit the common external form of hornblende—that is to say, sections taken at right angles to the "c" axis present the usual combination of prism faces 110 and clinopinacoids 010, with the characteristic domination of the prism faces. In colour and every other aspect these crystals present a striking similarity to those which appear to be clearly of secondary origin. It may also be noticed that the crystals which present the external form of hornblende, so far as I have observed, never show an interior of augite. These crystals are usually much smaller in size than those of undoubted secondary origin. It seems quite possible, then, that some of these dolerites may contain both original and secondary hornblende.

Mr. T. H. Holland has pointed out that in certain augite-diorites with micropegmatite from India both secondary hornblende and biotite occur. He has also found that hornblendic decomposition of the augite has progressed much more extensively in those parts of the rock where the mesotasis has been most abundantly developed. He further points out that the hornblende and biotite are always to be found along the margins of the augite, and that the secondary changes in the augite are much more marked when that mineral is in contact with the micropegmatite than when it abuts against the felspar.

Hypersthene.—Throughout these sills of dolerite a rhombic pyroxene is often to be met with. Its distribution is somewhat sporadic, as in some sills it appears to be exceedingly abundant, while in others it is entirely awanting. It usually crystallises in short, stout columns, which are idiomorphic in the prism zone. It also occurs in grains, showing no evidence of external form. When idiomorphic, the faces in the prism zone are the macropinacoid 100, the brachypinacoid 010, and the prism 110. When fresh, the hypersthene is of a pale brown or brownish-yellow colour, and it exhibits a well-marked pleochroism, which is as follows:—

α Pale yellow.
β Pale greenish yellow.
γ Green.

In a thin section of a dolerite from the Kilsyth district the

Digitized by Google

mineral appears to occur in two generations, there being an early crop of comparatively large crystals and a later crop of much smaller ones.

Olivine.—Olivine is an abundant mineral in almost all the dolerites of the Clyde valley. It occurs in well-shaped crystals, grains, and granular aggregates. Perfectly idiomorphic crystals are, however, comparatively rare. When unaltered, olivine has a yellowish-green colour in the mass, but in thin sections it is nearly colourless. The double refraction is strong, and chromatic polarisation bright. Olivine in all stages of alteration, from the perfectly fresh, glassy condition to crystals which have become completely serpentinised, may be met with in these intrusive dolerites. The most completely altered crystals are found along the margins of the sills, and the unaltered olivine appears to be confined to their centres. The alteration of the olivine commences at the surface, and gradually extends inwards along the lines of fissure in the crystals. Owing to the ramification and intersection of these cracks the crystal is divided into a series of irregular compartments, whose centres are composed of unaltered olivine surrounded by walls of green, serpentinous material. As the process of decomposition proceeds the serpentinous material creeps over the unaltered portions, and the crystal becomes entirely converted into a pseudomorph of serpentine, in which the original fissures and cleavage may be traced in the characteristic mesh-like structure of the serpentine. The majority of the crystals of olivine have suffered from corrosion by the magma, and this accounts for the general absence of well-shaped crystals. This deformation may extend to the complete obliteration of the original form, and the crystal is represented by a rounded grain, in which no trace of the original faces can be seen. The crystals are often seen to be penetrated by strings and bays of the ground mass.

Mica.—A dark mica, probably biotite, is exceedingly abundant in many of the dolerites, thin sections from the Necropolis and Cathcart intrusions being particularly rich in this mineral. It occurs in irregular scales and long, lath-shaped plates. Like much of the hornblende, this mineral seems to arise from the decomposition of the ferromagnesian constituents of the rock.

Digitized by Google

In convergent polarised light it gives a uniaxial interference figure. The scheme of pleochroism is as follows:—

α A clear pale yellow.
β Dark brown.
γ Dark brown.

Apatite.—Apatite occurs as an accessory mineral, its common habit being long, slender, hexagonal needles, which are quite colourless, and are often seen to penetrate the other constituents, so that one crystal may pass through both the felspar and the augite, thus showing that it is one of the oldest secretions of the magma. As a rule, it appears to be fairly uniformly distributed through the dolerites, but in some sections the crystals of apatite are closely crowded together into nests and strings.

Analcite.—Secondary analcite occurs in many of the dolerites. It is generally associated with plagioclase felspar, from which it has no doubt been produced as a decomposition product. This mineral is specially abundant in thin sections from the Hogganfield intrusion, where it fills up large spaces between the plagioclase and augite. The analcite is colourless, and may be either perfectly transparent or turbid in ordinary light. When viewed under crossed nicols it is occasionally isotropic, but more often exhibits its characteristic weak and irregular double refraction. Inclusions of what appear to be flecks and irregular fibrous masses of other zeolites are common within the analcite.

Besides the analcite just described, which is clearly of secondary origin, this mineral also occurs in certain of the sills in such a manner as scarcely to leave a doubt that it is one of the original constituents of the rock.

Iron Ores.—Magnetite and pyrites are the principal iron ores found in the dolerites. The former mineral occurs in black grains and octahedrons, which, even in the thinnest sections, are quite opaque. Seen by reflected light, magnetite presents a bluish-black metallic lustre. This mineral has been one of the earliest constituents of the dolerite to crystallise, as it may be found enclosed in all the other minerals of which the dolerites are composed. If a specimen of dolerite rich in magnetite be crushed, it will be found that a magnet will attract a large proportion of the grains forming the powder. Mr. H.

Digitized by Google

W. Monckton, in his paper on the Stirling dolerite, has pointed out that at Sauchieburn the dolerite is so strongly magnetic that it affected the compass of a level which was being used in a survey for the laying of a pipe track. Small specimens of this rock were also found to show distinct polarity.

V. The Intersertal Material.

One of the most interesting petrographical features in these rocks is the presence of a variable amount of intersertal material, mesostasis, or ground mass. The term intersertal-structure was given by Rosenbusch to a structure seen in certain porphyrites which are characterised by the presence of an interstitial substance filling in the angles between the felspar and pyroxenes. The intersertal material or mesostasis is found most abundantly in the central portions of the sills, and becomes much scarcer as we proceed towards the margins. It consists of the usual intergrowths of quartz and felspar. The proportion of quartz and felspar in the angular spaces varies a good deal, but, as a rule, there appears to be a gradual increase in the quartz towards the centres of the intersertal areas. A micromiarolitic structure is occasionally to be met with in the micropegmatite, the walls of the cavities being lined with minute crystals of quartz and the centres infilled with chloritic material. The felspar of the micropegmatite has, in many instances, become kaolinised when it presents the usual turbid appearance; when stained with iron the decomposed felspar of the micropegmatite gives a characteristic reddish colour to those patches of the rock which have been affected.

A thin section from the southern portion of the Stirling sill, near Frankerton, west of Denny, has been shown to me by Mr. G. W. Tyrrell, of the Glasgow University. The section contains a large quantity of intersertal material, and exhibits very clearly all the details of its structure and mode of occurrence. Round the walls of the intersertal cavities in this specimen there occurs a band of varying width of exceedingly fine micropegmatite, which often exhibits a regular and beautiful micrographic structure. This band of micropegmatite might also be described as forming a fringe round the plagioclase, with which under crossed nicols it may often be seen to be in optical continuity.

Digitized by Google

Towards the centre of the intersertal areas the material is generally much coarser, and may either consist of an aggregate of grains of quartz and felspar or of single masses of these minerals. Similar structures have also been observed by me in the same sill from the neighbourhood of Stirling.

Various theories have been advanced to account for the excess of silica in rocks of this type. Stecher believed that the silica in these rocks had been derived by the fusion of portions of the sedimentary rocks among which they have been intruded, and the assimilation of these portions by the intrusive rock. Others have considered that the micropegmatitic groundmass has been due to secondary changes induced in the rock.

Professor Sollas, in a paper on "The Relation of the Granite to the Gabbro of Barnavave, Carlingford," has endeavoured to show that the intersertal material in the gabbro was injected into that rock in a condition of extreme fluidity at some period subsequent to the consolidation of the gabbro from a later granophyric intrusion. He has also applied this explanation to other districts, as, for instance, the enstatite-diorite of Penmaenmawr and the augite diorite of Carrock Fell.

Mr. T. H. Holland, in the paper already cited, has arrived at the conclusion that the micropegmatite in these rocks must be looked upon as a primary constituent due to the consolidation of the original magma. His views are based upon the facts that the felspar exhibits a crystalline continuity with the plagioclase of the rock, that the mode of occurrence of the micropegmatite filling in, as it does, the spaces between the augite and the felspar, supports this view, and, lastly, that the variation in the coarseness of the grain of the micropegmatite with the other constituents of the rock points to a similar conclusion.

Mr. Holland insists that the separation of the acid and basic materials in the magma may be most easily explained on exactly the same principle as that which is so well known to occur on a large scale in plutonic complexes. In the cooling magma the silica and alkalies have a tendency towards the centre of the mass, while the ferromagnesians move outwards towards the margins. This view of the mode of differentiation has also been adopted by Dr. J. J. Harris Teall and Mr. A. Harker.

Digitized by Google

Digitized by Google

the appearance of long laths or fibres. At times the crystals appear to be grouped into radiating aggregations, and in some instances look as if they had been frayed out at the ends. Some of the longer crystals measure over an inch in length. By transmitted light the augite has a deep golden brown colour, while some of the crystals show the purplish-brown tint which is supposed to indicate a variety of augite rich in titanium. Many of the lath-shaped augites show a distinctly parallel arrangement, thus pointing to a certain amount of flow structure before the final consolidation of the rock. Inclusions of magnetite in bands running parallel with the longer axis of the crystals are exceedingly common. Zonal and hour-glass structures are not uncommon. The augite may be looked upon as the most abundant mineral constituent of the rock.

Plagioclase felspar is the next most abundant constituent of the rock. Like the augite, it also occurs in lath-shaped crystals. Irregular masses lying between the augite and the other mineral constituents are not uncommon. In association with the felspar, there occur large areas of analcite, which fill up the spaces between the other minerals. It never presents any evidence of crystalline outlines, and I regard it as of secondary origin. The other minerals which are present include irregular scales and plate of dark mica, apatite, and magnetite.

Another section from the margin of the same sill shows the augite to be present both in well-defined idiomorphic crystals and also in minute grains. The crystals exhibit the ordinary habit of augite, and are bounded by the faces 110, 010, 100, 001, 111. Twinning upon the orthopinacoid is fairly common. The granular augite appears to be grouped into masses of varying size, in the centre of which the idiomorphic crystals are often seen to occur. Olivine in rounded and much-corroded crystals is fairly common; they invariably show some evidence of decomposition, some of the crystals being only altered round the margins and along the cracks, while others have been completely decomposed into a bright green serpentine. Magnetite and apatite also occur abundantly in this slide.

A section of the dolerite from Miller Street shows it to be petrologically the same rock as that just described from Dennistoun. The augite and olivine are in an advanced stage of

Digitized by Google

decomposition, but the mineral constituents and general character of the rock are sufficient to show that it belongs to the same intrusion as the Necropolis and Dennistoun sill.

Cathcart.—Thin sections of the Cathcart dolerite taken from below the castle rock show very characteristic examples of the passage of the augite into hornblende, and these may be observed in all stages of alteration. The general process of alteration has already been described, and need not again be referred to. A more detailed description of some of the crystals seen in the sections will now be given. One crystal has been cut approximately at right angles to the "c" axis, and shows very clearly that the alteration has taken place in such a manner that the plane of symmetry and vertical axis are common to both minerals. The line of demarcation between the hornblende and augite is a comparatively sharp one, and there are about equal areas of hornblende and augite. In other sections, also cut approximately at right angles to the "c" axis, the hornblende is represented merely as a marginal fringe surrounding the augite. In some cases almost the whole crystal has passed into hornblende, and only the smallest speck of augite can be detected near the centre of the hornblende, while in the most advanced stage of alteration the augite has entirely disappeared. It may frequently be observed that a pleochroic band of purplish-brown augite intervenes between the marginal fringe of hornblende and the kernel of non-pleochroic brownish-yellow augite. This may represent an intermediate stage in the process of alteration. In a number of cases the junction line between the hornblende and augite, though well defined, is exceedingly ragged or irregular. In sections cut parallel to the "c" axis an irregular zone of hornblende may be observed more or less completely surrounding an internal kernel of augite. Analcite is abundant in one of the sections, and appears to play the rôle of groundmass much in the same manner as quartz in granite. The mode of occurrence of the analcite in the Cathcart rock seems to suggest that it might be an original constituent of the rock, and differs in this respect from that just described in the Dennistoun dolerite, which is clearly of secondary origin. Crystals of augite, hornblende, and plagioclase penetrate the analcite as if it had been the last mineral to consolidate. I

Digitized by Google

am indebted to Mr. G. W. Tyrrell, of the Glasgow University, for the kind permission to examine this slide. A specimen of the chilled edge of the Cathcart dolerite shows the rock to be much closer in the grain and more compact than the specimens just described. The augite occurs in the granulitic condition between the felspar. Alteration into hornblende is rare. Vacuoles filled with calcite and zeolitic material are numerous.

The Cathcart rock, then, consists mainly of augite, brownish hornblende, plagioclase, analcite, and apatite, and might be paralleled with the teschenite of Hohenegger, which occurs in intrusions on the Cretaceous rocks of Silesia and Moravia. The constituent minerals, their character and mode of occurrence, point to the similarity of the two rocks. In both rocks the augite has a violet tint, is strongly pleochroic, and often passes into hornblende along the margins. Apatite and analcite are also abundant in both rocks, while, structurally, they resemble each other in being characteristically non-ophitic. A somewhat similar rock has been described by Dr. Teall from Car Craig, in the Firth of Forth. The Inchcolm picrite presents a similar association of augite and hornblende as is seen in the Cathcart dolerite. It is also worthy of note that the well-known intrusive sill of Salisbury Crags, Edinburgh, presents petrological characters of exactly the same type as the Cathcart rock. A thin section in my possession shows a rock consisting largely of idiomorphic augite and plagioclase, the augite being of the purplish-tinged pleochroic variety; as accessory constituents, apatite and magnetite do occur. Here, again, as in the Cathcart rock, analcite is abundant, and apparently plays the part of groundmass, as the augite and plagioclase are often seen to penetrate the analcite in such a manner as to forcibly suggest the idea that the analcite must have been the last constituent to consolidate in the cooling rock.

Glenboig.—A sill of dolerite appears in the Millstone Grit close to the railway station at Glenboig. This sill is interesting, inasmuch as it presents the most perfect example of ophitic structure which I have yet observed in these rocks. It has already been remarked that the structure is comparatively rare among these rocks, and appears to be mostly confined to the margins of the sills. The Glenboig dolerite consists principally of augite and felspar, both of which are in a fresh condition.

Digitized by Google

The felspar occurs in the usual lath-shaped forms, and appears to have formed at a slightly earlier stage than the augite. The augite occurs in irregular polysomatic plates, which envelop and are penetrated by the felspar. No mesostasis is present, and the rock might be described as having a holocrystalline ophitic structure. A somewhat similar rock is found at Johnstone and Elderslie, to the west of Paisley.

Whiteinch.—The thin veins of tachylite which shoot out from the Whiteinch intrusion have already been described, and need not be further noticed. The dolerite of the main sill has been much altered. Augite and plagioclase have formed the bulk of the rock. The augite is much decomposed, having everywhere passed into a bright green chlorite. The plagioclase has also been much altered, and has become turbid through decomposition. Calcite and chlorite occur as secondary decomposition products. Grains of secondary quartz are also fairly common.

Kilsyth.—The Kilsyth sill is especially interesting, owing to the abundance of hypersthene which it contains, as well as augite and plagioclase. The hypersthene occurs both in small well-formed idiomorphic crystals, and also in larger crystals, which are not so perfectly idiomorphic; it is strongly pleochroic in green and greenish-yellow. Nests of skeleton crystals of magnetite occur abundantly in some portions of the rock.

Dundonald and Craigie.—At Dundonald and Craigie, in Ayrshire, an extensive sheet of dolerite has invaded the Millstone Grit and Carboniferous Limestone series. At its junction with the sedimentary rocks the Craigie sill is seen to send off veins and sheets into the surrounding strata. A thin section of the Craigie dolerite, taken from near the margin of the sill, shows that the chilled edge has a hypocrystalline structure. The felspar occurs in minute, lath-shaped crystals, which are polysynthetically twinned. Augite occurs in grains and granular aggregations. Phenocrysts of olivine in a highly corroded condition are plentifully scattered through the rock. A deal of magnetite is also present. A careful examination of the rock shows that it contains a large quantity of interstitial matter in the form of a dark-brownish glass, which under crossed nicols is perfectly isotropic. I have observed a somewhat peculiar structure in a section of the chilled edge, which, so far as I have been able to find, has not as yet been noticed by petro-

Digitized by Google

graphers. Throughout the rock just described occur a large number of oval- or circular-shaped aggregations of crystals and glass, the largest of which do not exceed 1 mm. in diameter. These aggregations usually consist of a central nucleus of granular augite, lath-shaped felspar, and brown glass. Round this nucleus there is a zone of interfelted crystals of plagioclase, and succeeding this, and forming the rim of the structure, is a narrow zone principally composed of granular augite, which makes a sharp line of demarcation between the structure itself and the surrounding rock. This line is also further emphasised by the absence of magnetite within the structure, and by its abundance in the surrounding rock. The structure just described may be taken as the most common and most typical that I have observed, but there appear to be occasional departures from it. Thus, in some instances the brown glass may be entirely absent from the central nucleus, and augite and plagioclase alone be present; while in others no central nucleus can be observed, and the entire structure consists of lath-shaped felspar and granular augite. I have not as yet been able to arrive at any satisfactory explanation of the phenomena exhibited by these peculiar nest-like structures. Grains of foreign quartz showing resorption borders are abundant in sections of the chilled edge, and so are vacuoles filled with chlorite and calcite.

The next section which I describe is taken about 5 feet above the line of contact. In this section no glassy base can be seen, the rock consisting of a holocrystalline aggregate of augite, hornblende, and plagioclase, with magnetite and apatite as accessory minerals. The plagioclase occurs in the usual form. Fresh augite is abundant, and there is no evidence of paramorphism into hornblende. Many of the augite crystals, however, exhibit the pale purplish tinge which is often associated with the passage of the augite into hornblende. Sometimes this colour forms a narrow band round the edge of the crystal; at others the whole crystal has this purplish tint. Analcite occurs in the same manner as has been described in the Cathcart rock. Secondary hornblende is absent, but small crystals of original hornblende are abundant in the rock. Cross sections of these exhibit the common habit of hornblende, and in many cases they can be seen to be completely isolated in a groundmass of analcite.

Digitized by Google

All the thin sections which I have examined of the Dundonald sill are characterised by the abundance of olivine which they contain. Towards the edge of the sill it appears to play quite as important a part in the mineral composition of the rock as the augite or plagioclase. It shows the usual irregular indented outlines due to corrosion, and can be easily identified owing to its characteristic green colour. The shape and colour of olivine gives this mineral a striking resemblance to broken bits of green bottle glass. The crystals or grains are traversed by numerous irregular cracks, along which decomposition has begun to take place. In the more coarsely crystalline portions of the sill olivine is also to be found, though it is by no means so abundant as in the marginal areas. The crystals appear to have suffered less from corrosion in the central portions of the sill than in the marginal parts.

REFERENCES.

1. Allport, S.—"On the Microscopic Structure and Composition of British Carboniferous Dolerites."—*Quart. Jour. Geol. Soc.*, vol. xxx., 1874, p. 529.
2. Waller, T. H.—"Observations on the Structure of Rowley Rag."—*Midland Naturalist*, vol. viii., 1885, p. 265.
3. Clough, C. T.—"The Whin Sill of Teesdale as an assimilator of the surrounding beds."—*Geol. Mag., dec.* ii., vol. vii., 1888, p. 433.
4. Young, J., and Glen, D. C.—"Notes on a section of Carboniferous Strata, containing Erect Stems of Fossil Trees and beds of Intrusive Dolerite in the old whinstone quarry, Victoria Park, Lower Balshagray, near Whiteinch and Partick."—*Trans. Geol. Soc. of Glasgow*, vol. viii., 1888, p. 227.
5. Teall, J. J. Harris.—*British Petrography*, 1888.
6. Rutley, F.—"On Tachylite from Victoria Park, Whiteinch, near Glasgow."—*Quart. Jour. Geol. Soc.*, vol. xlv., 1889, p. 623.
7. Holland, T. H.—"On Augite-diorites with Micropegmatite in Southern India."—*Quart. Jour. Geol. Soc.*, vol. liii., 1891, p. 405.
8. Sollas, W. J.—"On the Relation of the Granite to the Gabbro of Bamavare, Carlingford."—*Trans. Roy. Irish Acad.*, vol. xxx., 1894, p. 477.
9. Monckton, H. W.—"On the Stirling Dolerite."—*Quart. Jour. Geol. Soc.*, vol. li., 1895.
10. Geikie, Sir Arch.—"The Geology of Eastern Fife," 1902, p. 390.
11. Falconer, J. D.—"The Igneous Geology of the Bathgate and Linlithgow Hills."—*Trans. Roy. Soc. Edin.*, vol. xli., 1905, p. 359; and vol. xlv., 1906, p. 133.

Digitized by Google

EXPLANATION OF PLATES.

PLATE V.

Fig. 1.—Sill of dolerite exposed in the railway cutting at Arklestone, near Paisley. The dolerite has found its way along the line of the Hurlet Coal. At the north-east end, and top of the section, occurs the Hurlet Limestone, having a thickness of 2 feet 3 inches, which is immediately underlaid by about 6 inches of alum shale. Below the shale come the Hurlet Coal and the dolerite.

Fig. 2.—Junction of limestone, coal, and dolerite, Arklestone cutting, near Paisley. The coal has been rendered columnar by contact with the dolerite. The columns are nowhere very large, but they have been well formed. The arrangement of the columns into a series of tiers resting upon each other is well shown in the photograph. The columns in some of the tiers are seen to be inclined to those immediately above and below it.

PLATE VI.

Fig. 1.—Porphyritic dolerite from intrusive sill near Hogganfield × 20. Across the centre of the section lies a long crystal of augite, which has been bent into a straggling curve. The crystal has not been broken, but the anomalous refraction at certain points when the major portion of the crystal is in the position of extinction, shows that it has been subjected to considerable strain.

Fig. 2.—Dolerite from sill at Craigpark, Dennistoun × 20. One of the crystals of augite exhibits hour-glass structure; this has been formed by the filling in of the original skeletal crystal with material of somewhat different chemical composition.

Fig. 3.—Dolerite from sill at Necropolis, × 15. The minerals shown are plagioclase, augite, magnetite, and apatite. The plagioclase has the usual lath-shaped form. The augite occurs in grains and idiomorphic crystals.

Fig. 4.—Hypersthene dolerite from intrusive sill near Kilsyth × 15. The dark crystals seen in this section are all hypersthene, which occurs in well-shaped crystals and which can at once be identified by its characteristic pleochroism. The remaining part of the rock consists almost entirely of finely-striated plagioclase, felspar, and augite.

Fig. 5.—Dolerite from intrusive sill at Cathcart × 15. The rock consists principally of augite, hornblende, and felspar, with magnetite and apatite as accessory minerals. In the centre of the section is seen a crystal of augite, surrounded by a fringe of hornblende. In this instance the hornblende is clearly of secondary origin, as it presents the same faces as the augite from which it has been derived as an alteration product.

Fig. 6.—Tachylite from intrusive vein at the Fossil Grove, Whiteinch, × 25. The rock has cooled rapidly in the thinner veins and shows a glassy base, through which are scattered numerous spherulites. The spherulites are arranged in bands which run parallel to and lie close to the walls of the vein. Under the microscope the spherulites exhibit a divergent fibrous structure, which show a black cross between crossed nicols.

I have to acknowledge my indebtedness to Mr. J. W. Reoch and Mr. S. Fingland for a number of the photographs illustrating this paper.

Digitized by Google

PROCEEDINGS FOR SESSIONS 1905-1906 AND 1906-1907.

(48TH AND 49TH SESSIONS.)

SOCIETY'S ROOMS, 207 BATH STREET, 12TH OCTOBER, 1905.

The first meeting of the 48th session of the Geological Society of Glasgow was held here this evening.

The CHAIRMAN (Mr. Steel) intimated the death of Mr. M'Lennan, Hon. Librarian, and made feeling reference to the great loss which the Society had sustained by the removal of Mr. M'Lennan from our midst. He had occupied the post of Librarian for a long period of time, and had taken a very great interest in the working of the Library. It was agreed that the Secretaries be instructed to send a letter of condolence to Mrs. M'Lennan and family.

Mr. JOSEPH SOMMERVILLE gave notice that at the next meeting of the Society he would move that the constitution of the Society should be amended and brought up to date.

Mr. DAVID NIMMO exhibited a number of specimens collected by the members of "Camp Siluria" from the Silurian Rocks of the Logan Water, near Lesmahagow. These included some fine examples of *Slimonia acuminata*, *Pterygotus bilobus*, *Eurypterus obesus*, and also a number of specimens of a new genus of crustaceans probably allied to the *Phyllopoda*, but whose exact affinities have not yet been determined.

Mr. MACNAIR, Joint Hon. Secretary, made some remarks upon the specimens, and Professor M. Laurie, D.Sc., F.R.S.E., in whose hands the material has been placed for determination and description, reported upon the progress which he had made with these somewhat obscure fossils.

Mr. JAMES STARK read a paper entitled "Notes on the Geology of Glasgow's Highland Park." [See *Transactions*, vol. xiii., p. 4.]

Mr. JAMES NEILSON also read a paper entitled "Notes on an Ascent of Ben Macdhui," in which, after describing the general configuration of the mountain, he gave an account of its glacial phenomena. Near the bottom of Glenderry, which is flat and practically level for nearly five miles, there has evidently been the bed of an old lake, and it is not difficult to see how this lake has been formed, as the glen is crossed by no fewer than three moraines. The first of these passes within a few yards of Derry Lodge. It goes right across the glen, but is cut through near both ends by streams. The continuations of the moraine can be traced on the high ground on both sides of the glen. At a distance of half a mile and a mile further north there is a second and third moraine. The whole of the glen from the first

Digitized by Google

to the third moraine has at one time formed the bottom of one or more—probably three—moraine-dammed lakes, the lower of which would be the oldest, although it is quite possible that the whole three might have existed at one time. Proceeding to deal with the rocks of Ben Macdhui, the author discussed in some detail the manner of weathering of the granite, contrasting it with the granite of the Island of Arran. The beautiful quartz crystals known as the "cairngorm," he said, must now be very rare, as it seems that few have been found for a number of years. The flora of Ben Macdhui is very rich and mostly Alpine, being situated at over 3000 feet above the sea, and being surrounded by mountains from 700 feet to 1000 feet over that, and in the month of June, when the ascent was made, many of the plants were in flower.

After a vote of thanks to the authors of papers and the contributors of specimens, the Society adjourned till the evening of November 9th proximo.

SOCIETY'S ROOMS, 207 BATH STREET, 9TH NOVEMBER, 1905.

The second meeting of the 48th session of the Geological Society of Glasgow, being the Annual Business Meeting, was held here this evening.

Mr. JOSEPH SOMMERVILLE referred to the loss that the Society had sustained through the death of Mr. John Dansken. He was elected a member of our Society in 1877, was a member of Council for a number of years, and was Vice-President from 1893 to 1896. Although he did not profess to be a geologist, and took little active part in the scientific work of the Society, no man had a keener regard for the welfare and usefulness of the Society. He was one of those who believed that in a long life like this there was room in this Society for members who had only an imperfect knowledge of the science, and no one ever did more than he to increase the membership. He took an active part in other scientific work in the city, especially that allied science, astronomy. Mr. Dansken died, after a very short illness, on 1st November, and was buried on Saturday last in Lambhill Cemetery. It was agreed that the Secretary should be instructed to send a letter of condolence to Mrs. Dansken in her sad bereavement.

Mr. P. MACNAIR, Joint Hon. Secretary, read the Report of Council for the past year 1904-1905, which stated that the membership had rather decreased owing to deaths and resignations, while the number of accessories has not been sufficient to make up the loss from these causes; and it is hoped that members will do all they can to add to the roll of the Society by placing the advantages connected with it before their friends.

Mr. E. HALL WIGHT, Hon. Treasurer, submitted his Financial Statement for 1904-1905, which showed a satisfactory condition af affairs. Owing to the distressing event of the death of your late Hon. Librarian, Mr. J. S. M'Lennan, last month, the customary statistics will not be forthcoming.

These reports being all approved, were unanimously passed.

Digitized by Google

On the motion of Mr. STARK, seconded by Mr. BLAIR, the retiring office-bearers were thanked for their labours on behalf of the Society during the year.

Mr. BLAIR read a letter from Mr. Murdoch, in which he said that he deeply regretted the inability to carry on the work of the Society, but it was impossible for him to be present at the meetings, as he could not be out so late at night. He would always, however, continue to take a great interest in the Society and its work, and he left the post that he had held so long knowing that the work would be worthily carried on by Mr. Macnair and the gentleman who was to be appointed Joint Hon. Secretary. Mr. Blair said that he voiced the thought of every member of the Society when he said that we all regretted the retiral of Mr. Murdoch from active service. He had done a great work for the Society, having spared neither time nor labour in advancing its interests, and it was not likely that we should get such a Secretary in a hurry, for his shoes would be difficult to fill. He knew that Mr. Murdoch was followed in his retiral by the best wishes of every member of the Society, and he hoped that he would be long spared, and that we might still see him occasionally in our midst. He moved that Mr. Murdoch's letter be printed in the proceedings of the Society. He further moved that the Council consider some means of recognising the services of Mr. Murdoch, and also Mr. Wight.

The meeting then passed to the election of office-bearers to fill the vacancies occurring at this time, and there being just as many names proposed as were required for the purpose, the following gentlemen were declared duly elected for three years:—

As President—Mr. B. N. Peach, LL.D., F.R.S., F.G.S., proposed by Mr. John Renwick, Mr. Joseph Sommerville, Mr. J. B. Murdoch, and Mr. Peter Macnair

As Vice-President (one vacancy)—Mr. Robert Dron, A.M.Inst.C.E., proposed by Mr. Joseph Sommerville and Mr. John Renwick.

As Secretaries (two vacancies)—Mr. Peter Macnair, proposed by Mr. Joseph Sommerville and Mr. John Renwick; Mr. F. Mort, M.A., B.Sc., F.G.S., proposed by Mr. J. B. Murdoch and Mr. Peter Macnair.

As Treasurer—Mr. E. Hall Wight, proposed by Mr. Joseph Sommerville and Mr. John Renwick.

As Librarian—Mr. William Sinclair, proposed by Mr. John Renwick, Mr. Joseph Sommerville, Mr. J. B. Murdoch, and Mr. Peter Macnair.

As Members of Council (four vacancies)—Mr. Alexander Laird, proposed by Mr. Mathew Blair and Mr. David Chalmers; Mr. J. W. Gregory, D.Sc., F.R.S., Professor of Geology in the University of Glasgow, proposed by Mr. J. B. Murdoch and Mr. Peter Macnair; Mr. James Steel, proposed by Mr. William Sinclair and Mr. M. Blair; Mr. Archibald A. Young, proposed by Mr. James Stark and Mr. John Renwick.

As Auditors—Mr. Mathew Blair and Mr. David Pearson.

The following gentlemen were elected Ordinary Members of the Society:—(1) Mr. John William Fyfe, 221 West George Street, proposed by Mr.

Digitized by Google

James Barr and Mr. William Lyle; (2) Mr. Alexander M'Lean, 466 St. George's Road, proposed by Mr. Peter Macnair and Mr. J. B. Murdoch; (3) Mr. James Chisholm, 68 Main Street, Renton, proposed by Mr. Peter Macnair and Mr. J. B. Murdoch; (4) Mr. John Carmichael, 1086 Argyle Street, proposed by Mr. J. MacNaught Campbell and Mr. Peter Macnair; (5) Mr. Robert K. Paton, 17 Stanmore Road, Mount Florida, proposed by Mr. James R. Menzies and Mr. E. Hall Wight.

As Associate Members—(1) Miss Amanda I. Kling, 33 West End Park Street, Glasgow, proposed by Mr. Peter Macnair and Mr. J. B. Murdoch; (2) Mr. Duncan Smith, 3 Albion Street, Paisley, proposed by Mr. Peter Macnair and Mr. J. B. Murdoch; (3) Mr. Matthew S. Brodie, 72 Love Street, Paisley, proposed by Mr. Peter Macnair and Mr. J. B. Murdoch; (4) Mr. George B. Elliot, 33 Millbrae Road, Langside, proposed by Mr. Peter Macnair and Mr. J. B. Murdoch; (5) Mr. John Rioch, 1095 Pollokshaws Road, proposed by Mr. Peter Macnair and Mr. J. B. Murdoch; (6) Mr. James Drylie, 65 Morrison Street, S.S., Glasgow, proposed by Mr. Peter Macnair and Mr. J. B. Murdoch; (7) Mr. A. G. Campbell, 13 Clifford Street, Ibrox, proposed by Mr. Peter Macnair and Mr. J. B. Murdoch; (8) Mr. Roy N. Mirza, c/o Wallace, 104 Hill Street, Garnethill, proposed by Mr. Peter Macnair and Mr. J. B. Murdoch; (9) Mr. Hugh G. Martin, 4 Stanley Street, W., Glasgow, proposed by Mr. Peter Macnair and Mr. J. B. Murdoch.

Mr. JOSEPH SOMMERVILLE, in terms of notice of motion given at the August meeting, moved that the constitution of the Society be revised and brought up to date.

Mr. ARCH. DONALDSON exhibited specimens of *Osteolepis microlepidotus Ag.* from Stonegun Quarry, Thurso. These specimens, he said, were quite new, as the fish had been preserved in the solid, and could be completely separated from the matrix, so that the dorsal and ventral sides were exhibited covered with scales and plates.

Professor J. W. GREGORY, F.R.S., exhibited a native gold mill from Rhodesia. The mill had been formed in quartzite, and was originally part of the solid rock, the crushing stones being rounded balls of diorite. He also gave a brief account of the early working of gold in Rhodesia, and showed the probable high antiquity of the mill.

Mr. JAMES NEILSON exhibited a number of specimens of *Spirifera*, showing the spirally-coiled arms, and gave an account of how these internal structures could be developed by the use of acids.

Mr. JOHN MAIN read a short notice of the life and geological work of the late Mr. J. S. M'Lennan, Hon. Librarian, and said—"It was with much regret that we learned, about a month ago, that our highly-respected Hon. Librarian had gone over to the great majority. Mr. James M'Lennan belonged to an old stock of Ayrshire farmers, and first saw the light of day in Ochiltree on 22nd January, 1839. He received his education in Beith, and afterwards entered the F.C. Training College. For forty-five years Mr. M'Lennan was actively engaged in teaching, and he not only

Digitized by Google

left the impress of his sterling qualities on hundreds of his pupils, but he also took a very active part in every good cause in and around his own district. His laudable and amiable example carried in it such a secret and powerful efficacy as could not but make impressions on the young and rising generation. He had a profound reverence for the Bible. None of the modern discoveries shook for one moment his confidence in the revelations of the Gospel. Very widely read in modern literature, he grew more and more convinced that science and religion must go hand in hand, and that he who would part them asunder was the friend of neither, but the enemy of both. For over twenty years he had been an active member of our Society, and Hon. Librarian for eleven years. He proved himself to be as anxious for the welfare of his neighbours as for his own. Mr. M'Lennan was a great admirer of Burns."

After a vote of thanks to the contributors of specimens and papers, the Society adjourned.

SOCIETY'S ROOMS, 207 BATH STREET, 14TH DECEMBER, 1905.

The third meeting of the 48th session of the Geological Society of Glasgow was held here this evening.

The following members were elected :—

As Ordinary Members—(1) Mr. John Ferguson, M.A., LL.D., Professor of Chemistry in the University of Glasgow, 13 Newton Place, proposed by Mr. J. Sommerville and Mr. E. Hall Wight; (2) Mr. John Frew, M.A., 17 Highbury Road, proposed by Mr. F. Mort and Mr. D. Chalmers; (3) Mr. Robert Hunter, 7 Dryburgh Gardens, Kelvinside, N., proposed by Mr. F. Mort and Mr. D. Chalmers; (4) Mr. James Lambie, M.B., L.F.P. & S., Kilwinning, proposed by Mr. J. Smith and Mr. Archibald Shanks; (5) Mr. E. M. Anderson, H.M. Geological Survey, Geological Survey Office, Edinburgh, proposed by Mr. P. Macnair and Mr. J. B. Murdoch; (6) Mr. C. T. Clough, M.A., H.M. Geological Survey, Geological Survey Office, Edinburgh, proposed by Mr. J. Renwick and Mr. J. Sommerville.

As Associate Members—(1) Mr. P. Arthur Leitch, 1 Woodview Terrace, Hamilton, proposed by Mr. Peter Macnair and Mr. J. B. Murdoch; (2) Mr. Richard Robertson, M.A., Blanefield, Rutherglen, proposed by Mr. F. Mort and Mr. D. Chalmers; (3) Mr. Andrew Barclay, 14 Lorne Terrace, Maryhill, proposed by Mr. P. Macnair and Mr. J. B. Murdoch; (4) Mr. John Boyd, Brena, Mount Vernon, proposed by Mr. P. Macnair and Mr. J. B. Murdoch; (5) Mr. Alexander B. M'Call, c/o Young, 6 Warwick Street, S.S., proposed by Mr. P. Macnair and Mr. J. B. Murdoch; (6) Mr. F. Lesley Robertson, 8 Park Circus Place, proposed by Mr. P. Macnair and Mr. J. B. Murdoch; (7) Mr. John Redpath, c/o Taylor, Early Braes, Shettleston, proposed by Mr. P. Macnair and Mr. J. B. Murdoch; (8) Mr. J. W. Imrie, 5 Ashfield Gardens, proposed by Mr.

Digitized by Google

P. Macnair and Mr. J. B. Murdoch; (9) Mr. Thomas W. M'Clew, c/o Mrs. Mitchell, 54c Kirkness Street, Airdrie, proposed by Mr. P. Macnair and Mr. J. B. Murdoch; (10) Mr James R. Ogilvy Wills, 5 Ashfield Gardens, Jordanhill, proposed by Mr. P. Macnair and Mr. J. B. Murdoch.

Mr. James Currie, M.A., F.R.S.E., President of the Edinburgh Geological Society, read a paper on the "Faroe Islands." At the outset, he stated that it was peculiarly appropriate that his lecture should be given to the Glasgow Geological Society, as in its *Transactions* had recently appeared one of the most important contributions to the mineralogy of the group by the late Professor Heddle. A line from Edinburgh to Cape Wrath, and produced the same distance, would strike the Faroes. The group consists of about a score of islands, 17 of which are inhabited. There are three topographical features that strike the observer. First, he will notice the escarpments that stretch from hill to hill for many miles. Then he sees the peculiar valleys that mount by steps over the faces of the escarpments and terminate in rounded ends or corries. Most striking are the stupendous ocean cliffs that, on the west coast, stretch for miles as sheer precipices from 1000 to 2000 feet high. In graphic language the lecturer depicted the slow carving out of stack, and arch, and islet, by the resistless fury of the Atlantic. The island consists mainly of igneous rocks, with some beds of lignite and coal. Numerous sills stand out prominently owing to their superior weather-resisting properties, while, in strong contrast, many dykes have been eroded into ravines and caves. The lavas are porphyritic and amygdaloidal, and contain many interesting minerals. The steam cavities are sometimes very large, and are generally lined with chalcedony or opal. The rocks, as a whole, strongly resemble those of the Inner Hebrides, but their contours are much more jagged and serrated. The islands have been much glaciated and *striæ*, *roches moutonnées*, and polished surfaces are numerous. Ice markings have been observed to a height of 1400 feet, but they are now being rapidly obliterated by vigorous denudation. The chief biological interest of the Faroes centres in its birds. There are 140 species of these, but only 12 are common. In the catching of the sea fowl the Faroese are seen at their best. Having climbed up the precipitous rock faces from below, or having been lowered from above, an expert fowler will catch from 600 to 800 birds in a day. Their daring has, of course, its inevitable results, and 10 per cent. of the deaths are due to accidents. The lecturer then touched on the other industries of the islands, and also gave interesting descriptions of their history, the personal appearance and social conditions of their inhabitants, their flora, and their means of communication. At the close of the address a series of beautiful lantern slides was shown to illustrate the various points of the lecture. Mr. Currie was awarded a hearty vote of thanks for his interesting paper.

Mr. Sommerville moved, "That the constitution, as revised by the Council, become the constitution of the Society." He was seconded by

Digitized by Google

Mr. Menzies. Mr. Jolly, seconded by Mr. Gemmell, moved, as an amendment, that the matter be postponed for fuller discussion till next meeting. On a vote being taken, the motion was declared carried by 8 votes to 3.

The Society then adjourned till the 11th January, 1906.

SOCIETY'S ROOMS, 207 BATH STREET, 11TH JANUARY, 1906.

The fourth meeting of the 48th session of the Geological Society of Glasgow was held here this evening. Mr. Renwick drew the attention of the members to the testimonial to be presented to Dr. Peach, President of the Society, on the occasion of his retiral from the Geological Survey of Scotland.

Mr. SOMMERVILLE spoke of the death of Dr. Gloag, for many years corresponding member of the Society.

The following members were elected as Associate Members:—(1) Miss Agnes T. Neilson, 123 North Frederick Street, Glasgow, proposed by Mr. P. Macnair and Mr. F. Mort; (2) Mr. David Fyfe, F.R.C.S.E., F.F.P.S.G., L.D.S., 7 Fitzroy Place, Sauchiehall Street, W., proposed by Mr. Peter Macnair and Mr. F. Mort.

Mr. MACNAIR exhibited and made remarks on specimens of thorite and monazite recently presented to Kelvingrove Museum. These minerals are interesting as the source of the rare oxides used in the manufacture of incandescent gas mantles and Nernst lamps. Mr. Neilson exhibited stalactites from Buxton and dolomite from Sunderland, and gave a racy description of interesting geological features in these districts. Professor J. W. Gregory, D.Sc., F.R.S., then read a paper on "The Glaciation of a Limestone Surface at Lugton, Ayrshire." [See *Transactions*, vol. xiii., p. 10.]

Mr. GEMMELL gave notice that at next meeting he would move, "That the constitution of this Society be considered at the next ordinary meeting with a view to revising and amending the following rules, viz.:—

"Rule IV. To amend so as to define the time when a member is in arrears and not entitled to the privileges mentioned in the rule.

"Rule XIII. To amend so as to define how many members must be present to constitute (*a*) an ordinary meeting; (*b*) a special meeting.

"Rule XV. To amend so that the *Transactions* of the Society be published not later than (say) six months after the close of the session."

Mr. JAMES NEILSON, Milnbank, gave notice that at next meeting he would move, "That the constitution be recommitted for the consideration of the Society."

---

207 BATH STREET, GLASGOW, 8TH FEBRUARY, 1906.

The fifth meeting of the 48th session of the Geological Society of Glasgow was held here this evening.

Digitized by Google

Mr. PETER MACNAIR, Joint Hon. Secretary, exhibited, on behalf of Mr. John Smith, specimens of limestone containing blue and green carbonite of copper and iron pyrites, from Bowerhill, Heads of Ayr. Mr. Colin Livingston read a paper entitled "Further Considerations of the Problems presented by the Parallel Roads of Lochaber, and Various Proposed Solutions." [See *Transactions*, vol. xii.]

SOCIETY'S ROOMS, 207 BATH STREET, 8TH MARCH, 1906.

The sixth meeting of the 48th session of the Geological Society of Glasgow was held here this evening.

Mr. MURDOCH, editor of *Transactions*, communicated a notice of the life and work of the late Mr. J. G. Goodchild, F.G.S., of the Scottish Geological Survey, and Curator of the Survey collections in the Royal Scottish Museum, Edinburgh.

Mr. Goodchild was born near London in 1844, and joined the English Geological Survey in 1867. After mapping in the North of England for some years, he went to the offices of the Survey in Jermyn Street, London. In 1887 he came to Edinburgh, where he was placed in charge of the Survey collections. He edited the late Professor Heddle's important work on Scottish Mineralogy. If not at work in the Museum he was teaching students, lecturing at the Heriot-Watt College, or conducting excursions to various places. Besides all this work, Mr. Goodchild contributed a great number of papers to various scientific societies in Scotland and England. In 1893 he was awarded the balance of the Wollaston Donation Fund by the Geological Society of London. He contributed many papers to this Society, led excursions, and helped it in a great many ways. The following resolution was unanimously agreed to :—

"That the members of the Geological Society of Glasgow desire to place on record their great appreciation of the valuable work done by the late Mr. J. G. Goodchild in the field of general geological investigation, more especially in Scotland, and their sense of the loss caused by his death, and that they now beg to express their feelings of deep sympathy with his widow and family in their great bereavement."

Mr. Gemmell's motion was postponed in order that he might have the opportunity of moving it in person.

The following members were elected :—Mr. Charles Neilson, Thorncliff, Cathcart, proposed by Mr. David Chalmers and Mr. Hall Wight; Mr. Robert D. Stewart, Belinda Cottage, Shettleston, proposed by Mr. William Lyle and Mr. Arch. Donaldson; Mr. G. W. Tyrrell, Geological Department, University, proposed by Prof. J. W. Gregory and Mr. P. Macnair.

Mr. Sommerville reported the progress made with the testimonial to Messrs. Murdoch and Wight.

Mr. R. A. PATON exhibited a specimen of Sphærosiderite from the boulder clay at Mount Florida. He gave a detailed description of the mineral, and added a chemical analysis.

Digitized by Google

Mr. JAMES NEILSON read a paper entitled "Notes on the Geology of Mull and the Neighbourhood." He first described the topography of the island and the routes of the different excursions he had made. He then gave an outline of the geological history of the island. There is in Mull an almost unrivalled variety of rocks of different ages, from the Archæan gneiss up to the deposits of Tertiary age. At one time the island was covered with an enormous volcano, only the basal wrecks of which remain. Since then denudation has removed a thickness of rocks estimated at nearly 11,000 feet. The rocks at Ardtun Head are among the most interesting in Britain. River gravels are found full of chalk flints, and here also occur the famous leaf-beds of Mull. On the shores of Loch Alaine, lower Lias and lower Greensand beds crop out. These are highly fossiliferous, and numerous fine examples of fossils were exhibited in illustration of the paper. Specimens of rocks and a series of lantern slides also added to the interest of the paper.

Mr. F. MORT, M.A., B.Sc., F.G.S., Joint Hon. Secretary, read a paper entitled "The Extension Westwards of the Necropolis Intrusion." [See *Transactions*, vol. xiii., p. 19.]

SOCIETY'S ROOMS, 207 BATH STREET, 12TH APRIL, 1906.

The seventh meeting of the 48th session of the Geological Society of Glasgow was held here this evening.

Mr. GEMMELL stated that as we were within sight of the end of this session, he would withdraw his motion for the present.

Professor Peter Bennett, Technical College, was elected a member of the Society.

Mr. MACNAIR, Joint Hon. Secretary, exhibited a geologically coloured Relief Model of the Clyde Valley. He stated it would form one of a series of exhibits he was preparing for Kelvingrove Museum. Dr. Peach commented on the great educative value of the exhibit, and pointed out some interesting facts that were illustrated by the model.

Mr. JOHN FINGLAND read a paper entitled "Notes on the Distribution of Copper in the Cupriferous Pyrites Masses, Huelva District of Spain." The ore occurs in slates associated with sills of igneous rocks. The age of these rocks has been much discussed, but is still uncertain. Neither is there agreement of opinion regarding the origin of the mineral veins. Authorities cannot even decide whether the igneous rocks are interbedded or intrusive. The denudation of the region is particularly interesting from the fact that some of the rocks are strongly affected by insolation. This breaks down the hard igneous rocks more easily than the surrounding schists, and prevents the former from standing out prominently, as they do in this country. The mineral veins may be divided vertically into three zones, the richest zone being in the centre. The ore may appear foliated, unfoliated, or even as an agglomerate. Stalactites of various minerals are often found, the predominating compounds being sulphates of iron, copper, and zinc. The

Digitized by Google

poor ores are treated on the spot. They are exposed to the air for considerable periods and treated with water. The sulphides are thus oxidised to sulphates, which are recovered by solution. An explanation was then given of the process of concentration of the ore in Nature, and the necessary presence of the rich and poor zones was made clear.

Mr. PETER MACNAIR read a paper entitled "Petrological Notes on the Rocks Collected by Mr. J. Fingland in the Huelva District of Spain." The igneous rocks of the district fall into two groups—acid rocks and basic rocks. A quartz porphyry is found, which is in all respects a typical rock. Some of the pink felsites found are very fine in texture, but others are more easily identified. A particularly interesting rock is an augite porphyry consisting of orthoclase and augite. The basic rocks were then described. These are mainly basalts and dolerites, and call for little comment. The schistose rocks were next dwelt with, and it was shown that in some of these remains organic structure can still be detected.

Both papers were illustrated by numerous specimens and lantern slides.

The meeting concluded with votes of thanks to the contributors of the papers.

SOCIETY'S ROOMS, 207 BATH STREET, 10TH MAY, 1906.

The eighth meeting of the 48th session of the Geological Society of Glasgow was held here this evening.

Mr. RENWICK gave notice that at next meeting he would move, "That the sum of £15 of the Society's funds be devoted to the purposes of the Library."

Dr. PEACH announced the death of Captain Williamson, a member of the Society, and spoke of the high value of his work in local geology.

Mr. JOHN FREW, M.A., and Mr. FREDERICK MORT, M.A., B.Sc., F.G.S., Joint Hon. Secretary, exhibited drawings showing "The Southern Highlands from Dumgoyn." [See *Transactions*, vol. xiii., p. 23.]

Dr. B. N. PEACH, LL.D., F.G.S., read a paper entitled "Some New Points in the Geology of Dunnet Head, Caithness."

Note.—The Editors expect that this paper will be published in the next part of the *Transactions*.

Mr. PETER MACNAIR read a paper entitled "The Outcrop of the *Posidonomya punctatella* and *Estheria Youngii* Beds in the Waulkmill Glen." [See *Transactions*, vol. xii., p. 362.]

SOCIETY'S ROOMS, 207 BATH STREET, 7TH JUNE, 1906.

The ninth meeting of the 48th session of the Geological Society of Glasgow was held here this evening.

Mr. SOMMERVILLE referred to the loss sustained by the Society in the death of Mr. J. Barclay Murdoch of Capelrig, who joined the Glasgow

Digitized by Google

Geological Society in 1859, and for thirty years was Secretary and Editor of *Transactions*. It was agreed that the Society record in its minutes the deep sense of the loss it had sustained, and communicate the sympathy of the members with his family.

Mr. COWIE spoke of the contemporaries of Mr. Murdoch and the men of great ability with whom Mr. Murdoch had worked, but most of whom had predeceased him. Mr. Neilson, Milnbank, referred to the great labour and skill expended by Mr. Murdoch on the *Transactions*, and thought that more space should be devoted in them to the founders of the Society.

On the motion of Mr. Renwick, seconded by Mr. Sommerville, it was agreed that £15 of the Society's funds be devoted to Library purposes during the current session.

Mr. J. Drummond, 35 High Street, was elected a member of the Society.

Mr. F. L. ROBERTSON exhibited a specimen of Travertine encrusting moss from Limavady, County 'Derry, and gave some interesting notes on the locality in which it is found. Mr. Neilson made remarks. Mr. John Main read a paper entitled "The Story of Vesuvius, 63 A.D. to 1906." At the outset Mr. Main discussed the geographical position of Vesuvius and its relations with other volcanic centres. A brief history of the volcano was then given. At the middle of the first century of our era no eruption of Vesuvius had ever been known to occur. In the year 63 A.D. earthquakes occurred which finally culminated in the tremendous eruption of A.D. 79, when Herculaneum and Pompeii were destroyed, a vivid account of which is given in the letters of the younger Pliny to Tacitus. The speaker discussed at length the present appearance of the buried towns, and showed many views of their interesting features. The later eruptions were then dealt with in chronological order. The eruption of 1779 was noted for the great amount of liquid material poured from the mountain; 1859 was marked by a wonderful display of lightning, lasting for two months, while in 1892 160 feet were added to the height of the mountain. The outbreak of the present year was characterised both by lava and by ashes. In all three towns were annihilated, four were partially destroyed, and 500 lives were lost. The main points of the lecture were illustrated by a beautiful series of lantern slides. Mr. Stark discussed the causes of volcanic action with reference to certain points raised in the paper. Mr. Mort referred to new discoveries arising out of the recent eruptions. Mr. Cowie conveyed the thanks of the meeting to the speakers, and then declared the meetings of the session at an end.

SOCIETY'S ROOMS, 207 BATH STREET, 11TH OCTOBER, 1906.

The first meeting of the 49th session of the Geological Society of Glasgow was held here this evening.

Mr. ARCHIBALD A. YOUNG exhibited (1) Musical Sand, Island of Eigg; (2) Pitchstone from Scuir of Eigg; (3) Stinkstein from Seefield Limestone,

Digitized by Google

Alps; (4) Dolomitic Limestone from Ortler Spitze. Mr. Young also gave a short *résumé* of the new views regarding the structure of the Scuir of Eigg. Dr. Peach, who has personally taken considerable part in the recent researches, gave an interesting account of several new points that he and Mr. Harker have discovered.

Mr. F. Mort, M.A., B.Sc., F.G.S., and Mr. John Frew, M.A., B.Sc., contributed a paper on "The Southern Highlands from Gourock." [See *Transactions*, vol. xiii., p. 23.]

Mr. Peter Macnair read a paper on "The Occurrence of Magnetite in the Schists of Loch Long." The author first discussed the distribution of magnetite and pyrites in the Highland rocks in general. The pyrites seems o occur as a rule in more argillaceous bands. Both minerals are frequently distorted; their angles are rounded and fragments become detached. Shearing of the minerals is common, and a quantitative estimate of the shear was given for one example. Several typical localities were described in detail, and the conditions under which the minerals might have originated were suggested. Finally, the author gave a description of the magnetite schist band that crops out near the southern end of the Ardkinglas promontory. Both papers were well illustrated by numerous lantern slides prepared from photographs of the region under discussion.

Society's Rooms, 207 Bath Street, 8th November, 1906.

The second meeting of the 49th session of the Geological Society of Glasgow was held here this evening.

Mr. Macnair submitted the Report of the Council for the past session, which briefly touched on all matters of importance that had occurred throughout the year.

Mr. E. Hall Wight submitted the Treasurer's Report for the year, which showed that the Society was in a sound financial condition.

Mr. Sinclair reported on the condition of the Library, and mentioned the more important works added during the session. These reports were all unanimously adopted.

After a vote of thanks to the retiring office-bearers, the election of members to fill their places was proceeded with.

Professor Gregory, D.Sc., F.R.S., was unanimously appointed Vice-President.

The following gentlemen, *nemine contradicente*, were elected members of Council:—For three years—Messrs. Mathew Blair, C. R. Cowie, E. W. Gemmell, and J. W. Reoch. For two years—Mr. James Neilson (Milnbank).

On the motion of Mr. Renwick, Mr. Sommerville and Mr. Pearson were appointed Auditors.

The following members were elected:—

As Ordinary Members—(1) Mr. Spencer Mort, Viewfield, Partickhill,

Digitized by Google

proposed by Mr. F. Mort and Mr. D. Chalmers; (2) Mr. James Drylie, 45 Minard Road, proposed by Mr. E. Hall Wight and Mr. J. R. Menzies.

As Associate Members—(1) Mr. Andrew Barclay, 14 Lorne Terrace, Maryhill, proposed by Mr. P. Macnair and Mr. F. Mort; (2) Mr. James Morrison, 2 Church Road, Ibrox, proposed by Mr. P. Macnair and Mr. F. Mort; (3) Mr. Joseph Chapman, 24 Donaldson Street, Burnbank, Hamilton, proposed by Mr. P. Macnair and Mr. F. Mort; (4) Mr. Matthew S. Brodie, 72 Love Street, Paisley, proposed by Mr. P. Macnair and Mr. F. Mort; (5) Miss Amanda Kling, 33 West End Park Street, proposed by Mr. P. Macnair and Mr. F. Mort; (6) Miss Agnes T. Neilson, 41 West Cumberland Street, proposed by Mr. P. Macnair and Mr. F. Mort; (7) Mr. Duncan Smith, 3 Albion Street, Paisley, proposed by Mr. P. Macnair and Mr. F. Mort; (8) Mr. David Nicolson, Schoolhouse, Neilston, proposed by Mr. P. Macnair and Mr. F. Mort.

Mr. Sommerville gave notice that at next meeting he would move that £15 of the Society's funds be devoted to Library purposes during the current session.

Mr. Neilson (Milnbank) gave notice that at next meeting he would move —(1) that every new member shall receive a copy of the *Transactions* during his first year of membership; (2) that the constitution be altered to admit of the election of members at any meeting, providing their names appear in the circular calling that meeting.

On behalf of Mr. Dunlop, Mr. JAMES NEILSON exhibited the following specimens—(*a*) Fossils from the Silurian Rocks, Girvan; (*b*) Anthrapalæmon from Gullane and Airdrie; (*c*) Fossils from Pollok Pit, near Paisley; (*d*) Track of Gasteropod from Chryston. Many of the fossils from the Girvan district were in a particularly fine state of preservation. The fossils from Pollok Pit came from the coals and ironstones between the Upper and the Lower Carboniferous limestone. They included fine specimens of Lingula, Edmondia, and several plant remains.

Mr. TYRRELL exhibited a series of specimens showing differential weathering in the metamorphic rocks, and gave an interesting account of how each specimen had taken on its peculiar appearance.

Mr. STARK showed a number of rocks from the Heads of Ayr, including amygdaloidal basalt, gabbro, granite, and haggis-rock. In many cases he was able to state from what locality the rock had come, and by what agency it had most probably been transported.

Mr. NEILSON exhibited the following specimens:—(a) *Gyracanthus Youngii Traq.*, fish spines nearly two feet long; (b) *Rhizodus hibberti, Ag*, fish teeth nearly 10 inches long. Both the exhibits came from the middle iron and coal series, Dalry, and their exhibitor claimed that their equal could not be found in any museum in the kingdom. He then showed how the spines were attached to the body, and made some interesting remarks on the fish fauna of Carboniferous times. An interesting meeting concluded with a vote of thanks, proposed by the Chairman, to the contributors of specimens.

Digitized by Google

SOCIETY'S ROOMS, 207 BATH STREET, 13TH DECEMBER, 1906.

The third meeting of the 49th session of the Geological Society of Glasgow was held here this evening.

Mr. NEILSON (Milnbank) then moved that rule iv. of the constitution should be altered. He accepted a slight alteration in the wording of his motion, which then read as follows:—"All candidates for membership shall be proposed on the recommendation of two members, and their names announced in the circular calling an ordinary or special meeting, at which meeting their election shall be put to the vote from the chair. If not unanimous, the vote shall be taken by ballot."

Mr. Sommerville seconded, and the motion was carried.

Mr. NEILSON also moved, "That every new member of the Society receive a part of the *Transactions* during the first year of membership." After considerable discussion, it was agreed, on the motion of Mr. Chalmers, seconded by Mr. Gemmell, that the matter be remitted to the Council.

Mr. Sommerville moved, "That £15 of the Society's funds be devoted to the purposes of the Library during the current session." This was agreed to unanimously.

The following members were elected:—

As Ordinary Members—(1) Mr. John Hoggan, Castlecary Station, proposed by Mr. James Neilson and Mr. Fred. Mort; (2) Mr. R. G. Carruthers, H.M. Geological Survey, Edinburgh, proposed by Mr. Peter Macnair and Mr. F. Mort; (3) Mr. Arch. Downie, 30 St. Vincent Place, proposed by Mr. James W. Reoch and Mr. Peter Macnair.

As Associate Members—(1) Miss Nan Ormiston Neil, 87 Stanmore Road, Mount Florida, proposed by Mr. Peter Macnair and Mr. F. Mort; (2) Mr. R. N. Mirza, Glasgow and West of Scotland Technical College, proposed by Mr. Peter Macnair and Mr. F. Mort.

Mr. Sommerville congratulated the Chairman (Professor J. W. Gregory, D.Sc., F.R.S.) on his election to the Presidency of the Geological Section of the British Association, and expressed the pleasure the Society felt that one of their members should receive this honour.

Mr. E. W. GEMMELL then gave an interesting account of "A Holiday at Iona." The first portion of the paper consisted of a general description of the island, its ruins and its ancient monuments, special mention being made of the Cathedral, St. Martin's Cross, and the Culdee Cells. The lecturer was of the opinion that the work of restoration had not enhanced the artistic appearance of the Cathedral, and remarked that no artist of note had paid a professional visit to the island since the restoration. The geological formation of the different parts of the island was then described. Dun Island, Silver Rock, West Bay, Pigeon Cave, and the marble quarry were each dealt with in detail. Evidences of great earth movements are clearly visible, and the splintered and upturned rocks tell their own tale of intense forces at work in the early days of the earth's history. The rocks comprising the core of the island probably belong to the series

Digitized by Google

known as the Lewisian or Hebridean gneiss, and are enclosed on all sides by igneous rocks of granitic character. The schist along the east coast has probably been deposited over the older gneiss and hardened under the influence of great pressure and chemical action. These rocks may have been subjected to rupture, and the crevices filled up by limestone previous to the outburst of volcanic activity, and this may account for the beds of marble found in two portions of the island. Whether the limestones from which the marbles have been formed were precipitated deposits or animal formations it would be difficult to determine, as any organic structures would be completely destroyed by the subsequent alteration they have undergone. The lecture was illustrated by a large number of photographs specially taken by the lecturer, and specimens of the various rocks of the island were also exhibited.

SOCIETY'S ROOMS, 207 BATH STREET, 10TH JANUARY, 1907.

The fourth meeting of the 49th session of the Geological Society of Glasgow was held here this evening.

The following members were elected :—

As Ordinary Members—(1) Mr. A. W. Waddell, M.E., 4 Eton Terrace, Hillhead, proposed by Mr. Robert Dunlop and Mr. P. Macnair ; (2) Mr. John Macdougal, 37 Broomhill Drive, proposed by Mr. Spencer Mort and Mr. Fred. Mort ; (3) Mr. James Thomson Tullis, Ayton House, Dowanhill, proposed by Professor J. W. Gregory and Mr. E. Hall Wight.

As Associate Members—(1) Mr. F. Lesley Robertson, 8 Park Circus Place, proposed by Mr. P. Macnair and Mr. F. Mort ; (2) Mr. Matthew M. Monie, M.A., Kelvinside Academy, proposed by Mr. F. Mort and Mr. P. Macnair ; (3) Mr. Andrew Hutchison, M.A., 76 Douglas Street, proposed by Mr. J. Frew and Mr. Fred. Mort ; (4) Mr. Robert Boyle, c/o Rankine, 113 Renfrew Street, proposed by Mr. Fred. Mort and Mr. P. Macnair.

Mr. R. DUNLOP exhibited *Osmundites Gibbioni* and *Osmundites Dunlopi*, two new fossil ferns from the Jurassic formation of New Zealand. These are the first specimens of their kind ever discovered, and have created two new species. Photographs and some thin sections were also shown. The exhibitor described how the fossils had been found, and stated that Mr. R. Kidston, F.R.S., intended issuing a monograph describing them.

Mr. JAMES NEILSON exhibited specimens of *Lingula mytiloides* and *Discina nitida*. The specimens came from a quarry in Garngad Road, and various interesting features in the quarry were described. Three or four hundred of the latter fossil were shown on one slab, and Mr. Neilson suggested that when living they had been attached to seaweed.

Mr. J. W. REOCH exhibited a series of lantern slides, illustrating geological phenomena to be seen in the Giffnock quarries. Fine sections were shown illustrating false bedding, thinning out, unconformity, and synclines, as well as some of the organisms found in the rocks. The

Digitized by Google

exhibit was noteworthy both from its geological interest and the beauty of the slides from the photographic point of view.

Mr. JAMES STARK read a paper entitled "Notes on Certain Dykes in the Loch Long District."

Mr. JAMES NEILSON read a paper entitled "Notes on Gyracanthus and Gyracanthides."

Mr. P. MACNAIR read a paper entitled "Notes on some Examples of Irregular Bedding in the Giffnock Sandstones." The author first described various irregular features seen in the Giffnock quarries, which had been explained in two ways. Some held that they had been caused by a movement almost vigorous enough to be called a thrust-plane. Others explained them merely as irregularities of bedding. Mr. Macnair believed that a certain amount of motion must be admitted, and showed that even annelid tubes were found bent in one direction.

The various papers were illustrated by maps and lantern slides.

SOCIETY'S ROOMS, 207 BATH STREET, 14TH FEBRUARY, 1907.

The fifth meeting of the 49th session of the Geological Society of Glasgow was held here this evening.

Mr. SOMMERVILLE proposed that Mrs. J. B. Murdoch should be elected an Honorary Member of the Society, and it was stated that the Council, on his suggestion, had taken the matter up, and would put Mrs. Murdoch's name before the Society.

Mr. G. W. TYRRELL, Glasgow University, exhibited (1) artificial perlitic structure in Canada basalt; (2) a section of basalt from Dunglass Hill, Strathblane. Mr. Tyrrell explained how he had produced the perlitic structure by quick cooling, and showed different specimens of varying degrees of fineness. The section of basalt contained numerous clear microlites, with larger crystals of felspar, augite, magnetite, and a serpentinous substance, together with a little brown glass.

Messrs. R. G. CARRUTHERS and E. M. ANDERSON, M.A., B.Sc., of H.M. Geological Survey, read a paper entitled "The Stratigraphy of the Arden Basin."

Note.—The Editors expect that this paper will be published in the next part of the *Transactions*.

SOCIETY'S ROOMS, 207 BATH STREET, 14TH MARCH, 1907.

The sixth meeting of the 49th session of the Geological Society of Glasgow was held here this evening.

The following members were elected:—

As an Honorary Member—Mrs. J. B. Murdoch, Capelrig, Newton-on-Mearns, recommended by Council.

Digitized by Google

As Ordinary Members—(1) Mr. J. B. Elliot, 33 Millbrae Road, Langside, proposed by Mr. P. Macnair and Mr. F. Mort; (2) Mr. A. G. Campbell, 8 Walmer Terrace, Ibrox, proposed by Mr. P. Macnair and Mr. F. Mort; (3) Mr. D. A. Morrison, 97 High Street, Paisley, proposed by Mr. R. S. Houston and Mr. P. Macnair.

As Associate Members—(1) Mr. R. Harper, Myrtle Cottage, Early Braes, Shettleston, proposed by Mr. P. Macnair and Mr. F. Mort; (2) Mr. George Stratton, Mavis Mill, by Cambuslang, proposed by Mr. William Jolly and Mr. P. Macnair; (3) Mr. James Stratton, Mavis Mill, by Cambuslang, proposed by Mr. William Jolly and Mr. P. Macnair.

Mr. NEILSON exhibited a fine specimen of Allorisma maxima.

Mr. R. DUNLOP read a paper entitled "The Mineral Seams round Airdrie and their Fossils." [See *Transactions*, vol. xiii., p. 35.]

Mr. JOHN RENWICK and Professor J. W. GREGORY, D.Sc., F.R.S., read a paper entitled "The Loch Lomond Moraines." [See *Transactions*, vol. xii., p. 45.]

After giving a summary of the literature dealing with the district they proceeded to describe the Glen Fruin moraine. It is low compared with its length and rather sandy in nature. It is V-shaped, with the arms projecting east. The glacier that produced it, therefore, could not have come down Glen Fruin, but must have been an expansion of the sheet coming down Loch Lomond. There is a strong contrast in vegetation and the nature of the soil between the area enclosed by the moraine and the extra moraine area. Peat and rushes are seen in the former, while good turf is found in the latter. Erratics also are more numerous east of the moraine.

At Luss and at Rowardennan also shelves of drift are found about the same level as the Glen Fruin moraine, namely, 600 feet. The glacier has also left traces to the east of the loch in the Drymen district.

A moraine at Buchlyvie was next described, but its convexity pointing south-west shows that the ice did not come from Loch Lomond.

Interesting features in the drainage of the region were then described.

SOCIETY'S ROOMS, 207 BATH STREET, 11TH APRIL, 1907.

The seventh meeting of the 49th session of the Geological Society of Glasgow was held here this evening.

A letter was read from Mrs. Murdoch thanking the Society for her election as an Honorary Member.

Mr. SOMMERVILLE called the attention of the Society to the portrait of the late J. B. Murdoch, Esq., of Capelrig. He congratulated the Society on the admirable likeness that the artist, Mr. R. C. Crawford, had secured, and thanked Mr. Young, R.S.W., for the help he had given the portrait committee.

Mr. Jolly and Mr. Young also spoke.

Digitized by Google

Mr. A. J. Laird, A.M.I.M.E., Kelvinbank, Smith Street, Glasgow, was elected an Ordinary Member.

Mr. F. MORT, B.Sc., F.G.S., Honorary Secretary, exhibited hand specimens, microscopic sections, and lantern slides of the diamond bearing "blue-ground" of Kimberley. A brief account was given of the history of the discovery of diamonds in South Africa, the nature of the material in which they are found, and the methods of mining.

Mr. JAMES NEILSON exhibited teeth of Psammodus from the Lower Carboniferous limestones, Beith, and gave some interesting facts regarding these extinct sharks.

Mr. P. MACNAIR, F.R.S.E., Hon. Secretary, read a paper entitled "The Intrusive Dolerites of the Glasgow District." [See *Transactions*, vol. xiii., p. 56.]

Mr. JAMES NEILSON read a paper entitled "On the Occurrence of Megalichthys Hibberti (Agass.) in the Lower Carboniferous Strata."

Mr. NEILSON also read a paper entitled "Two Dry Channels near Dublin." The channels cross from one side of a hill to another, and are cut out of granite. They seem to be of comparatively recent origin. The generally accepted explanation is that the channels were cut out by the outflow of a lake formed by the damming up of water by ice. It is difficult to see, however, how the lake could have kept at such a uniform level for the long time necessary to excavate the channels.

SOCIETY'S ROOMS, 207 BATH STREET, 9TH MAY, 1907.

The eighth meeting of the 49th session of the Geological Society of Glasgow was held here this evening.

The PRESIDENT then read a paper entitled "The relation of the Geology to the Scenery of West Sutherland and Ross."

Note.—The Editors expect that this paper will be published in the next part of the *Transactions*.

SOCIETY'S ROOMS, 207 BATH STREET, 13TH JUNE, 1907.

The ninth meeting of the 49th session of the Geological Society of Glasgow was held here this evening.

The following members were elected:—

As Ordinary Members—(1) Mr. G. A. C. Bayne, Kerse Road, Grangemouth, proposed by Mr. P. Macnair and Mr. F. Mort; (2) Mr. W. Donald, 60 Firhill Road, Glasgow, proposed by Mr. E. Hall Wight and Mr. F. Mort.

As Associate Members—(1) Mr. J. B. Boyd, M.I.M.E., Gallowgate Street, Rothesay, proposed by Mr. P. Macnair and Mr. F. Mort; (2) Mr. James C. Wilson, c/o Brown, 15 Clarendon Street, Glasgow, W., proposed by Mr. F. Mort and Mr. P. Macnair.

Mr. JOHN FREW, M.A., B.Sc., and Mr. FREDERICK MORT, M.A., B.Sc., F.G.S., Hon. Secretary, exhibited drawings showing the Southern Highlands

Digitized by Google

from Glasgow. The points from which observations were taken were Ruchill Park and Springburn Park. These drawings conclude a series of surveys taken from several points in the Clyde Valley.

Mr. PETER MACNAIR, F.R.S.E., Hon. Secretary, exhibited, on behalf of Mr. Robert Dunlop, fossil shells from New Zealand, and a curiously marked slab of sandstone from Chryston. Fine specimens of Ostræ and Terebratula were shown.

Mr. WILLIAM JOLLY read a notice of the late Mr. James Barclay Murdoch of Capelrig, who for thirty years was Secretary of the Society. Mr. Murdoch was born in 1831 near Hobart Town, Tasmania, but came to this country at an early age. Members of his family had held high honours in the magistracy of Glasgow—one of them being Lord Provost. He was educated at Ayr Academy and the University at High Street, and left to go into business as a sugar refiner. In 1884 he inherited the estate of Capelrig, and thenceforward devoted all his time to literary and scientific pursuits. He was a man of the highest character, kind and courteous, and ever ready to help his friends in every possible way. He was taken away full-blossomed in years and honours, leaving a gap that will not be easily filled.

Reports were then read of recent excursions of the Society to Garabal Hill, Glen Fruin, Hamilton, and Lesmahagow.

EXCURSIONS FOR THE SEASON OF 1906.

To New Collieries at Olive Bank and New Craighall, Niddrie, Midlothian, on Saturday, 24th March—Mr. Robert Martin, manager, conductor—a joint excursion with Edinburgh Geological Society. For a description of these Collieries see a paper by Mr. Martin in the recently published part (vol. viii., part 3) of the *Transactions* of the Edinburgh Geological Society.

To South Queensferry, Linlithgowshire, on Saturday, 7th April—Mr. H. M. Cadell of Grange, B.Sc., conductor—a joint excursion with Edinburgh Geological Society. Oil shales and the Burdiehouse Limestone, with intrusive igneous rocks.

To Aberfoyle, Perthshire, on Saturday, 7th April—Mr. Peter Macnair, hon. secretary, conductor. The party entered the Loch Katrine Aqueduct where it cuts through the boundary fault, and proceeding northwards passed successively through the jasper beds, the black shales and cherts, and the grits. They then returned and examined the rocks on the south side of the fault; these include limestones, conglomerates of Old Red Sandstone age, and a bed of vesicular andesite interbedded with the conglomerates.

To Lesmahagow, Lanarkshire, on Monday, 16th April (Spring Holiday)—Mr. Peter Macnair, hon. secretary, conductor. In the Upper Silurian inlier of Lesmahagow, the rocks are folded into a dome-shaped anticline,

Digitized by Google

with the Wenlock rocks in the centre. These pass upwards into the Ludlow, Downtonian, and Old Red Sandstone formations. The party went by the Birkenhead Burn and returned by the Logan Water. An opportunity was thus given of examining the general structure of the inlier, and of visiting the principal fossiliferous horizons.

To Kilmacolm, Renfrewshire, on Saturday, 21st April—Mr. Alex. Laird, conductor. Glacial striæ, Gryfe Street; Rowantreehill Quarry; dolerite dyke of late Carboniferous age, being extension of dyke shown on Geological Survey Map from Rashielie, Inchinnan, to Haddockstone, 56 per cent. of which, when pulverised, attracted by magnet; denuded dyke through Knapps Moor, probably of Tertiary age; volcanic ash beds and lava flows near Gowkhouse Burn, the ravine cut by this stream showing fine effect of river erosion; Glen Moss, an ancient lake; Crag and tail, erratic boulders; Auchenbothie Quarry; the rock, when pulverised, being nearly all attracted by magnet; fine view of Gryfe Valley. Total walk was about three miles.

To Kilbirnie Waterworks, Ayrshire, on Saturday, 5th May—Mr. John Smith, conductor. The party proceeded up valley of Pundeavon Burn and line of pipe track to reservoir. Several lava flows were examined, one at reservoir being dug with the spade, having become decomposed by weathering, and some of its minerals converted into china-clay. Bosses of rock stick up amongst the rotted stuff. Minerals include barite, calcite, white saponite, Kilpatrick and common quartz, red stilbite, delessite and celadonite. On way back Glengarnock Castle (in ruins) was visited. Here the river Garnock has left its pre-glacial course and cut through rock; the old glen being filled with boulder-drift exceptionally thick. At the Castle the side of a volcanic vent can be seen, filled with agglomerate blocks, measuring up to 10 ft. in size. Distance walked was about six miles.

To Murroch and Auchenreoch Glens, Dumbartonshire, on Saturday, 12th May—Mr. James Neilson, conductor—a joint excursion with the Edinburgh Geological Society. Many lofty sections of the Ballagan group of shales and cement stones. Several intrusive dykes. Fine example of stream erosion. Minerals—Fibrous gypsum (pure white) and celestite. Distance walked was about six miles.

To Scotstoun, West, on Wednesday, 16th May (evening excursion)—Mr. Joseph Somerville, conductor. Excavations in post-glacial sands and gravels.

To Turnberry, Ayrshire, on Thursday, 24th May (Victoria Day)—Dr. B. N. Peach, F.R.S., F.G.S., president, conductor. Lower Old Red Sandstone lavas, representing over twenty flows, some of which are separated from each other by thin beds of sandstones, tuff, and breccia, which pass down into, and fill tissues and caverns in the original surfaces of cooling of the underlying lava flows. These rocks are cut by several dolerite dykes of Tertiary age. Drift; raised beaches, and blown sand. Walking distance was about five miles.

Digitized by Google

To Rouken Glen, Renfrewshire, on Wednesday, 30th May (evening excursion)—Mr. Peter Macnair, hon. secretary, conductor. The rocks exposed in the Rouken Park belong to the upper division of the Carboniferous Limestone Series, of which numerous fine sections are seen in the Glen. Near the bottom of the Glen the flaggy sandstones underlying the Arden limestone are well shown. Proceeding up the Glen the rocks in descending order include the Rouken Glen shales and limestones, which yielded such an abundant fauna when they were exposed in the Thornliebank Print Works some years ago. At the head of the Glen the Giffnock sandstones are faulted against the underlying volcanic rocks.

To Aberfoyle, Perthshire, on Saturday, 2nd June—Dr. John Horne, F.R.S., F.G.S., H.M. Geological Survey, conductor—a joint excursion with the Edinburgh Geological Society. (1) Lower Old Red Conglomerates and Sandstones; (2) cherts, black shales, limestones and grits of doubtful age on the Highland border; (3) grits and slates north of the latter group. Distance walked was fully six miles.

To Gleniffer, Renfrewshire, on Saturday, 9th June—Mr. Matthew Blair, conductor—a joint excursion with the Geological section of the Paisley Philosophical Institution. The party first visited the Linn, where an interesting section of igneous rock overlying volcanic ash, and forming the waterfall, was examined. Thereafter they proceeded to the old limestone workings at Nethercraigs, where abundant Carboniferous fossils can be obtained. They then passed up Gleniffer Glen and Gorge. Here a trap dyke, believed to be of Tertiary age, pierces the more ancient lavas. Emerging from the glen, in the new public park of Paisley, a superb view of the valley was obtained. The interesting glacial features and surface geology were explained.

To Joppa and Levenhall, Musselburgh, Midlothian, on Saturday, 16th June—Mr. David Tait, H.M. Geological Survey, conductor—a joint excursion with the Edinburgh Geological Society. On the west side of the Midlothian coal basin on the shore at Joppa the section exposed is about half-a-mile long. The beds include part of the Upper Limestone Series, the Millstone Grit (Roslin Sandstone), and part of the Lower Coal Measures; a total thickness of about 1500 feet of strata, well exposed and without much faulting. On the east side of the basin three miles further east, at Levenhall, the same beds again crop out, affording an opportunity of observing the variations in the strata. Though fossils are not very abundant in these sections, their palæontological interest is great, as they both contain the Lower and Upper Carboniferous Floras and Faunas, the change from Lower to Upper taking place suddenly in the Millstone Grit. Specimens of *carbonicola* can be easily collected, also a few plants.

To Mark, Ardkinglas Estate, Argyleshire, on Saturday, 23rd June—Mr. Peter Macnair, hon. secretary, conductor. The schists of which the mountainous peninsula of Glasgow's New Park is composed belong to the Ben Ledi Grit Series. They were originally formed as sedimentary deposits, but have been altered into Crystalline Schists by dynamic metamorphism.

Digitized by Google

An axis of folding passes near the head of Loch Long, and the area is one of intense plication and crushing. Numerous fine sections, illustrating the phenomena connected with dynamic metamorphism, were seen. Examples of felsite and basalt dykes, faults and fault-breccia, glaciation and raised beaches were also examined.

To Dunure and Heads of Ayr, Ayrshire, on Saturday, 4th August—Mr. James Stark, conductor. For a distance of eight miles southwards from the Heads of Ayr the rocks exposed along the coast are of Lower Old Red Sandstone age. They dip towards the north at an angle of 8 to 10 degrees, and attain a thickness of about 6000 feet. The lower members of the series are sandstone, passing into a great series of contemporaneous andesites, with occasional thin courses of conglomerates and sandstones indicating subaqueous deposition. The andesites contain agates and other minerals. Near Heads of Ayr a fine section of Upper Old Red rocks is exposed with sea-caves at various elevations, indicating changing sea-levels.

To Glen Culanach, Dumbartonshire, on Saturday, 18th August—Mr. John Renwick, conductor. The hollow called Glen Culanach appears to lie in the line of a fault stretching from Garelochhead through the head of Loch Long, up Glen Loin to the uppermost part of Loch Lomond, and onwards to the N.N.E. The physiography is interesting. Northwards the drainage is into Glen Douglas and Loch Lomond, southwards into Loch Long, the "divide" between the two sections being almost imperceptible, and at about the same level as that further north between Glen Douglas and Loch Long. The rocks consist of mica schists with two intrusive felsite dykes. In the Glen is a quantity of moraine matter.

To Bardowie, Stirlingshire, on Saturday, 1st September—Mr. Robert W. Dron, C.E., vice-president, conductor. Superficial glacial deposits along course of pre-glacial river channel. Outcrop of Hosie limestone and shale with underlying whinstone, Bardowie Loch occupying hollow in glacial drift. Cuttings in sands, &c.

EXCURSIONS FOR THE SEASON OF 1907.

To Gartsherrie Ironworks, Coatbridge, on Saturday, 23rd March—Mr. M'Cosh, jun., conductor—a joint excursion with Edinburgh Geological Society. The object of the excursion was, by kind permission of Messrs. Wm. Baird & Co., Ltd., to witness the various processes connected with the manufacture of iron; the charging of the furnaces with the various iron ores, home and foreign, with coke, coal, and limestone; the running off the molten iron, and the separation of the slag; the separation of the bye-products, tar and ammonia, from the green gases coming from the furnaces; the method of extracting oil and pitch from the tar. Tea was taken at Gartsherrie Institute.

To Loch Garabal, Dumbartonshire, on Monday, 1st April (Spring Holiday)—Professor J. W. Gregory, D.Sc., F.R.S., conductor. The

Digitized by Google

objects of the excursion were—(1) To examine the moraines in Glen Falloch at the foot of Srath Dubh-uisge, and those in the latter valley, which is a hanging valley left by the deepening of Glen Falloch; (2) to inspect at Loch Garabal the igneous complex described in the paper by Dakyns and Teall, and used by them as an instance of the formation of igneous rocks of different compositions from the same magma. They hold that all the rocks from the granite of Maol Breac to a peridotite on the shore of Loch Garabal are modifications of one intrusive magma. Walking distance about eleven miles.

To Glen Fruin, Dumbartonshire, on Saturday, 13th April—Prof. J. W. Gregory, D.Sc., F.R.S., and Mr. John Renwick, conductors. The object of the excursion was to examine the moraine described in vols. ix. and x. of the Society's *Transactions*, and again, by the conductors, at the meeting in March, 1907. Proceeding along the mounds of gravel and sand on Helensburgh Moor the line of the moraine is seen to turn eastwards on Bennchara Muir and run slantingly up the hillside. Lower down the valley is Dumfin, a huge hill of gravel. Near Meikle Dumfin farmhouse is a glaciated rock surface. Many boulders occur in this neighbourhood, the largest being that at Callendoun. To the north-east of Inverlauren the moraine is well developed and forms a prominent feature. Southwards, on the south-west side of the river, it is represented by mounds of sand with a little gravel.

To Hamilton, Lanarkshire, on Saturday, 20th April—Mr. A. Macintyre, F.S.A.A., conductor—a joint excursion with Edinburgh Geological Society. The party first visited Cadzow Forest, which contains the old oaks and the famous white cattle. They then proceeded by Cadzow Castle and the banks of the Avon, where for fully a mile there is a fine exposure of carboniferous strata — sandstones, shales, coal, &c.—with "ingaun e'es," and showing faults, landslips, river erosion (post-glacial), and in the river bed a variety of boulders and gravel. About 150 feet of different sedimentary deposits can be taken in at a glance of the eye, from the bed of the river to the red sandstone overlying the coals. Returning by the banks of the river, the shooting-lodge, Chatelherault, was seen on the way to the sand quarries. Thereafter Ferniegair Colliery was visited, where members descended the pit, and witnessed the working of the electrical coal-cutting machinery.

To Barrhead, Renfrewshire, on Saturday, 27th April—Mr. R. G. Carruthers, H.M. Geological Survey, conductor. The party examined the cuttings on the new Caledonian line south of Barrhead. The first section shows the Cowglen limestone and its characteristic associated strata, including a large cutting in the Barrhead grit. Proceeding east a section of the boundary fault was seen near Auchinback, where the Cowglen Limestone is thrown against a highly fossiliferous limestone resting on the ashes and lavas of the Calciferous Sandstone Series. Another exposure of the Cowglen Limestone was seen in the Waulkmill Glen Reservoir, and a visit was paid to the well-known Waulkmill Glen section, showing the succeeding beds up to the Arden Limestone.

Digitized by Google

To Ponfeigh and Douglas, Lanarkshire, on Saturday, 11th May—Mr. Robert W. Dron, C.E., vice-president, conductor. The party examined the strata of the Carboniferous Limestone Series, and of the Calciferous Sandstone Series, as exposed in outcrops along Ponfeigh Burn, and in mine at Douglas Colliery. The distance walked was about five miles.

To Garngad, Glasgow, on Wednesday, 15th May—Mr. James Neilson, Milnbank, conductor. The quarries near Garngad Railway Station were visited. These show soft sandstone, shale, and coal. The sandstone is wrought for moulders' sand, and the shale for fire-brick. The shale contains marine fossils. The sandstone is the only one in Scotland known to be charged with marine fossils; it contains also plant remains. The horizon is at the base of the Millstone Grit and the top of the Upper Limestone group.

To Lesmahagow, Auchenheath, &c., on Thursday, 23rd May (Victoria Day)—Mr. Peter Macnair, F.R.S.E., hon. secretary, conductor. Upon reaching Lesmahagow a number of sections in the Lower Old Red Sandstone were first examined. The party then proceeded to the river Nethan and followed its course to where it joins the Clyde at Crossford. Near Burnfoot the overlap of the Carboniferous upon the Old Red Sandstone rocks can be observed. Further down the stream fine sections in the Carboniferous Limestone series are exposed. At the base is seen the *Productus giganteus* bed, and an ascending succession is then passed over until the limestones pass into the Millstone Grit. Near Craignethan Castle there occurs a fault which throws the Millstone Grit against the limestones. An opportunity was given of examining the historic and picturesque Craignethan (Tillietudlem) Castle. The distance walked was about eight miles.

To Cuttings at Buchanan Street Station Extension, on Wednesday, 29th May—Mr. David Chalmers, vice-president, conductor. The object was to examine cuttings in sandstone and in boulder clay containing a variety of travelled boulders.

To Gourock, on Saturday, 8th June—Mr. F. Mort, M.A., B.Sc., F.G.S., hon. secretary, conductor—a joint excursion with the Geological Section of the Paisley Philosophical Institution. On arrival at Ashton the party proceeded along the shore and examined the section exhibited there of Lower Calciferous Sandstone age. The sandstone shows false bedding. Several intrusive dykes give examples of contact metamorphism. Marine pot-holing was seen. Proceeding up the hillside several contemporaneous lava flows were observed. From the hill-top, good illustrations of the dependence of scenery on geological structure were seen. Distance walked was about four miles.

To Blackhall, Paisley, on Wednesday, 19th June—Mr. Peter Macnair, F.R.S.E., hon. secretary, conductor. At Blackhall a sill of dolerite has pierced a series of shales, ironstones, and limestones which are well seen in the bed of the Cart at this point. The contact phenomena exhibited in the Blackhall section is exceedingly interesting, the line of junction between the dolerite shales and ironstones being well marked though very irregular.

Digitized by Google

Tongues of dolerite are seen to pass from the main intrusion into the shales incorporating portions of the sedimentary rocks, which vary in size from the smallest fragments up to large masses measuring several feet in length. Everywhere along the line of junction the shales have been much hardened, and a well-marked columnar structure superinduced upon them.

To Buchlyvie, Stirlingshire, on Saturday, 29th June—Prof. J. W. Gregory, D.Sc., F.R.S., conductor. The object of the excursion was to examine the "line of Kames strewn with blocks of Highland grit," on the southern side of the upper valley of the Forth, and its eastward extension towards Buchlyvie, evidently the remnant of the lateral, and part of the terminal moraine of a glacier which descended from the mountains surrounding the head of the Forth Valley. Beginning at Buchlyvie the moraine was examined as far westward as time permitted. The underlying rocks are sandstones and shales of Lower Old Red Sandstone age. Distance walked was fully seven miles.

To Dalry and Kilbirnie, Ayrshire, on Saturday, 3rd August—Mr. John Smith, conductor. The old copper mine at Swinlees was visited. The copper occurs as a green carbonate in porphyrite rock. On each side of the hill is Carboniferous Limestone (Lower Series). At Castle Hill pectolite occurs in gas cavities in dolerite. The extensive and fossiliferous quarries of Howrat were next examined. Distance walked was about eight miles.

To Motherwell and Dalzell, Lanarkshire, on Saturday, 17th August—Mr. Robert W. Dron, C.E., vice-president, conductor. The party examined the strata of the Coal Measures from the ell coal to the Drumgray coal as exposed on the banks of the Clyde in Dalzell policies and in underground workings at Dalzell collieries.

To Glen Douglas, Loch Lomond, on Saturday, 24th August—Mr. A. Park, conductor—a joint excursion with the Natural History Society of Glasgow. Glen Douglas is apparently a very old river valley deepened by ice action. On some of the hillsides are landslips, and in the main and side valleys traces of moraine matter. The rocks are schistose grits, belonging to the Ben Ledi grit horizon, into which are intruded dykes of felsite and basalt.

To Barrmill, Ayrshire, on Saturday, 7th September—Mr. James Neilson, Milnbank, conductor. Several quarries in the neighbourhood were visited, where was seen the Main and Upper Limestones of the Lower Limestone Series with their accompanying shales, containing numerous fossils. Distance walked was under four miles.

To Arthur's Seat, Edinburgh, on Saturday, 21st September—Dr. B. N. Peach, F.R.S., F.G.S., president, conductor—a joint excursion with Edinburgh Geological Society. The main object of the excursion was to consider the evidence that the so-called newer part of the hill consists of at least two vents which were active at different times, and which probably supplied materials to the bedded lavas and ashes of the dry dam and the Whinny Hill respectively.

Digitized by Google

To Dunure and Heads of Ayr, Ayrshire, on Monday, 30th September (Autumn Holiday)—Mr. John Smith, conductor—a joint excursion with the Natural History Society of Glasgow. The party proceeded to Dunure old Castle and walked northward along the shore, where were seen a number of volcanic flows of Old Red Sandstone age, of different qualities, some of them containing agates; Old Red Sandstone strata with fish remains; and Calciferous Limestones with fresh-water fossils and plants; the rocks in some places being traversed by large trap dykes. "The Heads" are formed by the debris of a volcano well-dissected by the waves. Near them are caves, occasionally inhabited. Distance walked was about six miles.

Digitized by Google

ABSTRACT OF TREASURER'S ACCOUNTS FOR THE YEAR ENDED 30TH SEPTEMBER, 1905.

CASH ACCOUNT.

RECEIPTS.

To Cash in Bank on Deposit, ...	£158 0 0		
,, Cash in Treasurer's hands, ...	5 11 4		
		£163	11 4
,, Subscriptions for current year (including 9 new Members)—			
160 at 10/-, ...		80	0 0
Do. do. —2 at 7/6, ...		0	15 0
,, Arrears— 14 at 10/-, ...		7	0 0
,, Life Membership Subscription, ...		5	5 0
,, Associate Members' Subscriptions—14 at 2/6, ...		1	15 0
,, Interest on Funds, ...		7	4 0
	£265	10	4

EXPENDITURE.

By Printing and Publishing Vol. XII., Part 2, of *Transactions*, ...	£44 0 0		
,, Reprints of Dr. Heddle's and Mr. Craig's Papers Vol. XI., Part 2, of *Transactions*, ...	1 0 0		
		£45	0 0
,, Printing Index and Introduction to the Geology and Palæontology of the Clyde Drainage Area, and binding Handbook, ...		8	19 9
,, Library—			
New Books, Maps, and Magazines, ..	£5 16 0		
Official Post Cards, Notepaper and Envelopes, ...	0 19 0		
		6	15 0
,, Subscription to Marine Biological Association for 1904 and 1905, ...		2	2 0
,, Subscription to Palæontographical Society for 1905, ...		1	1 0
,, Rent, Insurance, and Attendance, ...		13	10 0
,, Printing and Postage of Circulars, ...		19	17 3
,, Lantern Expenses, ...		1	16 0
,, Collector's Commission, ...		2	9 6
,, Disbursements by Honorary Secretaries, Postages, Stationery and Petty Expenses, ...		7	5 9
,, Loan to Corporation of Campbeltown on Gas Mortgage, ..		100	0 0
,, Cash in Bank on Deposit, ...	£50 0 0		
,, Cash in Treasurer's hands, ...	6 14 1		
		56	14 1
	£265	10	4

STOCK ACCOUNT.

To Life Subscriptions Account, ...	£252	0	0
,, Capital Account,*	574	14	1
	£826	14	1

* NOTE.—Subject to cost of publishing *Transactions*.

By Campbeltown Corporation Loan, ...	£270 0 0		
,, Cash in Bank and on hand, ...	56 14 1		
		£326	14 1
,, Property—			
Books in the Library, ...	£440 0 0		
Furniture, Bookcases, and Microscope, ..	60 0 0		
		500	0 0
	£826	14	1

GLASGOW, 2*nd November*, 1905.—Examined, compared with relative Vouchers and Securities, and found correct, the balance in Treasurer's hands being Six Pounds, Fourteen Shillings and One Penny.

J. NEILSON,
ARCH. A. YOUNG, } *Auditors.*

Digitized by Google

ABSTRACT OF THE TREASURER'S ACCOUNTS FOR THE YEAR ENDED 30TH SEPTEMBER, 1906.

CASH ACCOUNT.

RECEIPTS.			EXPENDITURE.		
To Cash in Bank on Deposit,	£50 0 0		By *Transactions*—		
,, Cash in Treasurer's hands,	6 14 1	£56 14 1	Half-tone Blocks, Views of Dumbuck Crannog, and 500 printed copies,	£3 19 2	
,, Subscriptions for current year (including 15 new Ordinary Members)—156 at 10/,		78 0 0	Reprints of Mr. Neilson's Paper, Vol. XII., Part 3, of *Transactions*,	1 6 0	
,, Do. do. —1 at 7/6,		0 7 6	Typing proceedings, per Publishing Committee,	0 5 4	
,, Arrears—3 at 10/,		1 10 0			£5 10 6
,, Life Membership Subscriptions—2 at £5 5s.,		10 10 0	,, Library—		
,, Associate Members' Subscriptions—20 at 2/6,		2 10 0	New Books, Maps, and Magazines,	£3 5 0	
,, Handbooks and Catalogues sold,		0 5 5	Disbursements by Librarian,	1 1 5	
,, Interest on Funds,		8 14 0			4 6 5
			,, Subscription to Marine Biological Association, 1906,		1 1 0
			,, Subscription to Palæontographical Society, 1906,		1 1 0
			,, Writing Address on Vellum "to the American Philo. Society,"		1 3 0
			,, Rent, Insurance, and Attendance,		13 12 0
			,, Printing and Postage of Circulars,		21 4 2
			,, Lantern Expenses,		1 16 0
			,, Collector's Commission,		2 11 0
			,, Disbursements by Hon. Secretaries, Postages, Stationery, and Petty Expenses,		5 1 9
			,, Cash in Bank on Deposit,	£95 0 0	
			,, Cash in Treasurer's hands,	6 4 2	
					101 4 2
		£158 11 0			£158 11 0

STOCK ACCOUNT.

To Life Subscriptions Account,		£262 10 0	By Campbeltown Corporation Loan,	£270 0 0	
,, Capital Account,*		608 14 2	,, Cash in Bank and on hand,	101 4 2	£371 4 2
			,, Property—		
			Books in the Library,	£440 0 0	
			Furniture, Bookcases, and Microscope,	60 0 0	
					500 0 0
		£871 4 2			£871 4 2

* NOTE.—Subject to cost of publishing *Transactions*.

LIFE SUBSCRIPTION ACCOUNT.

Sept. 30, 1906—To Balance to Credit,	£262 10 0	October 1, 1905—By Balance,	£252 0 0	
		Sept. 3, 1906—By Subscriptions during Year,	10 10 0	
	£262 10 0			£262 10 0

GLASGOW, 23*rd October*, 1906.—Examined, compared with relative Vouchers and Securities, and found correct, the balance in Treasurer's hands being Six Pounds, Four Shillings and Twopence.

MATTHEW BLAIR, } *Auditors*
DAVID PEARSON, }

Digitized by Google

THE

GEOLOGICAL SOCIETY OF GLASGOW,

INSTITUTED 1858.

OBJECTS OF THE SOCIETY—OFFICE-BEARERS FOR SESSION 1906-1907—CONSTITUTION OF THE SOCIETY—LIST OF MEMBERS.

1907.

Digitized by Google

THE GEOLOGICAL SOCIETY OF GLASGOW.

INSTITUTED 1858.

THE objects of the Society are the advancement of Geological Science by means of periodical meetings for its study; the reading and discussion of original papers on subjects illustrative of Geology and the allied sciences; the exhibition and description of Geological specimens; the delivery of lectures; and excursions to places of Geological interest accessible to Glasgow.

The meetings are held on the second Thursdays of each month, from October to May, and the excursions are made in the spring, summer, and autumn months, on Saturday afternoons or on public holidays.

There is a large library of books on Geological and kindred subjects, which is added to from time to time. The books can be borrowed by members for home reading.

The *Transactions* of the Society are published annually, and all members on the roll who are not in arrears of their subscription, are entitled to receive a copy of each part issued during their term of membership.

The Life-Membership Subscription is one payment of Five Guineas, and that for Ordinary Membership Ten Shillings per annum, payable on election, and thereafter on 1st October. There is no entry-money. Associate Membership for students and others attending Geological classes may be had at a subscription of 2s. 6d. per annum.

PETER MACNAIR,

FREDERICK MORT,

Honorary Secretaries.

Digitized by Google

THE
GEOLOGICAL SOCIETY OF GLASGOW.

Office-Bearers for Session 1906-1907.

President—

Dr. B. N. PEACH, LL.D., F.R.S., F.G.S.,

Vice-Presidents—

For Three Years.

Prof. J. W. Gregory, D.Sc., F.R.S.

For Two Years.	*For One Year.*
Mr. Robert W. Dron, C.E.	Mr. David Chalmers.

Members of Council—

Mr. Matthew Blair.	Mr. Alex. Laird.	Mr. John Main.
Mr. C. R. Cowie.	Mr. James Neilson.	Mr. John Renwick.
Mr. E. W. Gemmell.	Mr. James Steel.	Prof. A. H. Sexton.
Mr. J. W. Reoch.	Mr. Arch. A. Young.	Mr. James Stark.

Honorary Secretaries—

Mr. Peter Macnair, F.R.S.E., Kelvingrove Museum.

Mr. F. Mort, M.A., B.Sc., F.G.S., 116 York Drive, Hyndland.

Honorary Treasurer—

Mr. E. Hall Wight, 150 Hope Street.

Honorary Librarian—

Mr. William Sinclair, 45 Oswald Street.

Honorary Editors of "Transactions"—

Mr. Peter Macnair. | Mr. Frederick Mort.

Auditors—

Mr. Joseph Sommerville. | Mr. David Pearson.

COMMITTEES APPOINTED BY THE COUNCIL.

Printing and Publishing Committee—

Professor Gregory.	Mr. James Stark.	Mr. E. W. Gemmell.
Mr. E. Hall Wight.	Mr. C. R. Cowie.	Mr. P. Macnair, *Con.*

Library Committee—

Mr. Jos. Sommerville.	Mr. James Steel.	Mr. Arch. Young.
Mr. David Chalmers.	Mr. J. Neilson, M'bank.	Mr. W. Sinclair, *Con.*

Excursions Committee—

Professor Gregory.	Dr. B. N. Peach.	Mr. David Chalmers.
Mr. R. W. Dron.	Mr. James Steel.	Mr. J. W. Reoch.

Mr. John Renwick, *Convener.*

Finance Committee—

Mr. James Stark.	Mr. Matthew Blair.
Mr. James Steel.	Mr. R. W. Dron.

Mr. E. Hall Wight, *Convener.*

Photographic Committee—

Mr. J. W. Reoch.	Mr. C. R. Cowie.	Professor Sexton.
Mr. Alex. Laird.	Mr. S. Fingland.	Mr. W. Sinclair, *Con.*

The Honorary Secretaries are "ex-officio" Members of all the above Committees.

Digitized by Google

THE GEOLOGICAL SOCIETY OF GLASGOW.

INSTITUTED 1858.

CONSTITUTION as Amended,

SESSION 1905-06.

I.—NAME.

The Society shall be called "THE GEOLOGICAL SOCIETY OF GLASGOW."

II.—OBJECTS.

The objects of the Society shall be—

I. To unite, in permanent working association, the students and friends of Geological Science in Glasgow and surrounding districts.

II. The advancement of that science, by means of periodical Meetings for its study; the reading and discussion of Papers on subjects illustrative of Geology or its allied Sciences; the exhibition and description of specimens; the delivery of Lectures; and by Excursions.

III. The formation of a Library chiefly relating to Geology, Palæontology, Petrography, and Mineralogy.

IV. The publication of the Society's *Transactions* and *Proceedings*.

III.—MEMBERS.

The Society shall consist of Ordinary, Associate, Honorary, Honorary Associate, and Corresponding Members.

IV.—ORDINARY AND ASSOCIATE MEMBERS.

All candidates for Membership shall be proposed on the recommendation of two Members, at one Meeting, and their election put to the vote from the chair at the following Meeting, whether Ordinary or Special, provided their names shall have been

Digitized by Google

announced in the Circular calling the said Meeting. If not unanimous, the vote shall be taken by ballot.

The Annual Subscription shall be—for Ordinary Members—Gentlemen, 10s., and Ladies, 7s. 6d., payable upon election, and thereafter at the first Ordinary Meeting of each Session in October.

A single payment of Five Guineas shall entitle any Member elected as aforesaid to be entered as a Life Member.

Students attending Geological Classes shall be eligible for admission as Associate Members for the current Session at a Subscription of 2s. 6d., with the right of attending all Meetings and Excursions, and of using the Library, but not of voting, nor of receiving the *Transactions*.

Members whose Subscriptions are in arrears shall not be entitled to vote, nor to use the Library, nor to receive the *Transactions*.

Members shall be held liable for their Annual Subscriptions until they have given written notice of their resignation.

V.—HONORARY MEMBERS, HONORARY ASSOCIATES, AND CORRESPONDING MEMBERS.

The Ordinary Members shall have power to elect—on the motion of two of their number—Honorary Members, Honorary Associates, and Corresponding Members, at any Meeting, provided that notice of the said motion has been given at a previous Meeting and received the sanction of a majority of the whole Council. The votes of two-thirds of the Members present shall be requisite for the election of all such Members.

(1.) Persons distinguished for their attainments in Geology or the allied Sciences shall be eligible as Honorary Members. These shall be entitled to the same privileges as Honorary Members.

(2.) Persons resident in Glasgow or neighbourhood, who may have benefited the Society by services rendered, by donations of books, or by the contribution of original communications, shall be eligible as Honorary Associates.

(3.) Friends and Students of Geological Science resident at a distance from Glasgow, who may be willing to forward information or communications to the Society, shall be eligible as Corresponding Members.

Digitized by Google

Honorary Associates and Corresponding Members shall be entitled to attend the Meetings, Lectures, and Excursions, but shall have no vote in the management of its affairs, nor be entitled to receive copies of the *Transactions*, except at the discretion of the Council.

VI.—OFFICE-BEARERS.

The business of the Society shall be conducted by a Council of twenty-one, consisting of a President, three Vice-Presidents, two Secretaries, a Treasurer, a Librarian, an Editor of *Transactions*, and twelve Councillors.

The election of Office-Bearers shall take place by ballot, at the Annual General Meeting. The names of those proposed to fill the various offices, together with their proposers and seconders, shall be sent in to the Secretaries at least eight days before the Annual General Meeting, and submitted to a meeting of Council, and printed in the Circular calling that Meeting.

They shall take office for three years. The President, Secretaries, Treasurer, Librarian, and the Editor of *Transactions* shall be eligible for re-election. The senior Vice-President and the four senior Councillors shall not be eligible for re-election to such offices as those they retire from in rotation until they have remained one year out of office.

VII.—CHAIRMAN.

In the absence of the President, or by arrangement with him, one of the Vice-Presidents, or, failing them, a Member of Council, shall preside. The Chairman shall have a deliberative and a casting vote.

VIII.—SECRETARIES.

The Secretaries shall act both for the Society and the Council, and shall give due intimation of all Meetings of the Society and the Council, record the proceedings of the Meetings in the Minute-Books, prepare abstracts thereof for publication in the newspapers, keep a register of the names and addresses of Members and Associates, and conduct the general correspondence of the Society. They shall be *ex officio* members of all Sub-Committees.

Digitized by Google

IX.—TREASURER.

The Treasurer shall receive and pay (as authorised by the Council, or by any General or Special Meeting of the Society) all moneys connected with the Society, and shall keep a regular account of the same, which account shall be balanced as on the 30th September of each year, audited by two Members, who shall not be Members of Council at the time, and submitted to the Annual Business Meeting in November.

X.—LIBRARIAN.

The Librarian shall have charge of the Library and all other property belonging to the Society, and shall arrange and keep a Catalogue thereof.

The *Transactions* shall be exchanged with such Societies and Geological Authors at home and abroad as may be approved of by the Council. The Librarian shall have charge of such exchanges, and shall keep a correct list of the same. Members shall have access to the Library on the nights of Meeting, and at such other times as the Council shall arrange.

XI.—EDITOR OF TRANSACTIONS.

The Editor shall attend to the preparation of the material for the Society's *Transactions* and *Proceedings*. A Publishing Committee, of which the Editor shall be Convener, shall be appointed annually by the Council, and shall decide as to all papers or abstracts of papers to be printed, and the illustrations to accompany them.

XII.—COUNCIL.

The Council shall meet as often as may be requisite for the transaction of the Society's business, and five shall form a quorum. They may appoint Sub-Committees for the management of special business. They shall make arrangements for the Winter Session, and also for the Excursions. They shall prepare a report of the affairs of the Society for the past year to be submitted to the Annual General Meeting.

Any vacancy occurring during the year may be filled up by the Council; but such appointments shall only be for the unexpired portion of the previous occupant's term of office. Members so

Digitized by Google

elected shall, however, be eligible for re-election if their period of such office has not extended beyond two years.

XIII.—MEETINGS.

Ordinary Meetings of the Society shall be held once a month during the Session, commencing on the second Thursday evening in October, at eight o'clock, but more frequently if the Council should deem it advisable. At these Meetings the order of business shall be as follows:—The Minutes of the previous Meeting shall be read and confirmed; the vote taken on any candidates whose names have been duly proposed for Membership; the names of those applying for Membership submitted; specimens of geological interest exhibited and remarked upon; papers read and discussed, and any other competent business disposed of. The second Meeting of each Session shall be the Annual General Business Meeting, at which one of the Secretaries shall read the report of the Council for the past year; the Treasurer shall submit the Financial Statement; the Librarian shall report on the state of the Library, and the Editor of *Transactions* report on the progress of the Publications of the Society. The election of Office-Bearers shall then be proceeded with, and the ordinary business follow.

Special Meetings.

The Council shall be empowered to call, at any time when necessary, a Special Meeting of the Society, and shall be bound to do so on the written requisition of ten Members, specifying the business to be submitted thereto.

At all Meetings the resolutions of a majority of those present—with the exceptions stated in Laws V. and XVI.—shall be binding.

XIV.—VESTING OF PROPERTY.

The property of the Society shall belong solely to the Ordinary Members, and shall be vested for their behoof in the Council for the time being. The Council shall have the management of the property, and power to sell or otherwise dispose of any duplicate Books or copies of the *Transactions* at prices they may arrange. Any other property which they may consider unnecessary to retain shall only be disposed of with the consent of a majority of the Ordinary Members present at a Meeting of the Society, and notice shall be given in the Circular calling the Meeting of the intention to ask such consent.

Digitized by Google

XV.—APPLICATION OF FUNDS.

The Annual Subscriptions, and the annual revenue from Life-Membership Subscriptions, shall be devoted to the general work of the Society, special attention being given to the printing and illustrating of the Society's *Transactions*, of which all Ordinary Members shall be entitled to receive a copy of each Part published during their term of membership.

Should the Subscriptions at any time be insufficient for this purpose, the Council shall have power to fix such a charge for each Part of the *Transactions* as may be required to make up the deficiency.

Papers printed in the *Transactions* shall entitle the Authors to receive thirty copies of their papers free.

Sums may be voted from time to time by the Council for the Library and for other purposes out of any funds there may be on hand, but not exceeding Two Pounds in value without the sanction of a General Meeting.

The capital from the Life-Membership Subscriptions shall be retained as a separate Fund for the re-publication of such Memoirs or Parts of the *Transactions* as may become out of print, and be still in demand; for special Publications or of Exhibitions in connection with the visits of other learned Societies; and generally for such exceptional purposes as are not provided for by the Annual Subscriptions.

The Council shall obtain the sanction of a Meeting of the Society before applying any portion of this Fund in such way.

XVI.—ALTERATION OF THE CONSTITUTION.

No alteration shall be made in the Constitution of the Society except at a Meeting of which special intimation has been given by Circular issued for that purpose. Notice of any proposed alteration shall be made at the Meeting preceding, and shall not be adopted unless agreed to by two-thirds of the Members present.

XVII.

Any contingency not provided for in the foregoing Rules shall be submitted to the Council, and their decision shall be final and binding on all concerned.

Digitized by Google

THE GEOLOGICAL SOCIETY OF GLASGOW.

(INSTITUTED 1858.)

LIST OF MEMBERS, OCTOBER, 1907.

Honorary Members.

Year of Election.

1865. Geikie, Sir Archibald, D.C.L., LL.D., F.R.S., &c., Shepherd's Down, Haslemere, Surrey.

1867. Jones, T. Rupert, F.R.S., F.G.S., 17 Parson's Green, Fulham, London, S.W.

1867. M'Chesney, Joseph H., Professor of Geology, University of Chicago, U.S.A.

1871. Hull, Edward, M.A., LL.D., F.R.S., F.G.S., 20 Arundel Gardens, Notting Hill, London, W.

1872. Kelvin, Right Hon. Lord, G.C.V.O., D.C.L., LL.D., F.R.S., Netherhall, Largs, Ayrshire.

1883. Judd, J. W., C.B., LL.D., F.R.S., F.G.S., 22 Cumberland Road, Kew, London.

1888. Murray, Sir John, K.C.B., LL.D., F.R.S., F.R.G.S., Challenger Lodge, Wardie, Edinburgh.

1900. Gray, Mrs. Robert, 59 George Street, Edinburgh.

1902. Geikie, James, LL.D., D.C.L., F.R.S., F.G.S., F.R.G.S., Kilmorie, Colinton Road, Edinburgh.

1902. Horne, John, LL.D., F.R.S., F.G.S., Geological Survey Office, Edinburgh.

1902. Lapworth, Charles, LL.D., F.R.S., F.G.S., University of Birmingham.

1902. Peach, B. N., LL.D., F.R.S., F.G.S., Geological Survey Office, Edinburgh.

1902. Traquair, R. H., M.D., LL.D., F.R.S., F.G.S., Museum of Science and Art, Edinburgh.

1904. Jolly, Wm., F.R.S.E., Blantyre Lodge, Blantyre.

1907. Murdoch, Mrs. J. B., Capelrig, Newton Mearns

Digitized by Google

Honorary Associates.

Year of Election.

1867. Struthers, Thomas, Gourock.
1871. Horne, James, 71 Carlton Hill, St. John's Wood, London.
1871. Farie, James, Canonbury, London.

Corresponding Members.

1859. Dougall, John, M.D., 493 Shields Road, Glasgow.
1860. Sommerville, George, Thornliebank.
1864. Mitchell, Rev. Hugh, LL.D., Craig, Montrose.
1865. Winchell, Alex., Professor of Geology, University of Michigan, U.S.A.
1867. Kerr, David, Wemyss Colliery, Fifeshire.
1871. Jack, R. L., LL.D., F.G.S., 36 Overstrand Mansions, Battersea Park, London.
1871. Jamieson, T. F., F.G.S., Ellon, Aberdeenshire.
1871. Kinahan, G. H., late Geological Survey of Ireland, Dublin.
1871. Ward, John, F.G.S., 23 Stafford Street, Longton, Staffordshire.
1883. Scott, Thomas, F.L.S., Menzies Road, Torry, Aberdeenshire.
1884. Dobbie, J. J., M.A., D.Sc., Museum of Science and Art, Edinburgh.
1884. Nathorst, Professor Alfred Gabriel, Stockholm, Sweden.
1898. Livingston, Colin, Ardtraigh, Fort-William.

Ordinary and Life Members.

1905. Adams, John, 8 Nelson Place, Stirling.
1905. Anderson, E. M., H.M. Geological Survey, Geological Survey Office, Edinburgh.
1882. Anderson, James, 55 Gibson Street.
1898. Bain, James, Whins House, Alloa.
1894.*Barlas, George, 15 Ruthven Street.
1894.*Barr, Professor Archibald, Royston, Dowanhill, Glasgow.
1894.*Barr, James, M.I.C.E., F.S.I., 221 West George Street.
1893. Barr, Patrick, 51 Bath Street.
1907. Bayne, G. A. C., Kerse Road, Grangemouth.
1903. Beattie, William, Park Hall, Dalmuir.
1905. Begg, James L., Artist, Elms, Mount Vernon.
1900. Begg, Thomas, Elms, Mount Vernon.

Digitized by Google

Year of Election.

1906. Bennett, Professor Peter, Technical College, Montrose Street.
1902. Blackwood, Matthew, Ardmore, Port-Glasgow.
1889. Blair, Matthew, The Moorings, Thornley Park, Paisley.
1895. Brown, Rev. Alex., 4 Leslie Road, Pollokshields.
1887. Brown, Andrew, Bruce Villa, North Mount Vernon.
1892. Brown, John A., Dowanhill Gardens, Dowanhill, Glasgow.
1904. Buchanan, R. MacNeil, M.B., C.M., F.F.P.S.G., 2 Northbank Terrace, Kelvinside.
1904. Buchanan, W. Arthur, 18 Bute Gardens, Hillhead.
1894. Burnett, John James, A.R.S.A., 70 University Avenue, Hillhead.
1902. Burns, Daniel, M.I.M.E., Technical College, Montrose Street.
1907. Campbell, A. G., 8 Walmer Terrace, Ibrox.
1903. Campbell, Bailie Archd., Springfield Quay, Glasgow.
1877. Campbell, John MacNaught, 6 Franklin Terrace.
1905. Carmichael, John, 1399 Argyle Street.
1880. Carmichael, Robert S., Audit Office, St. Enoch Station.
1906. Carruthers, R. G., H.M. Geological Survey Office, Edinburgh.
1895. *Cassels, John, 154 Queen's Drive, Crosshill.
1895. Chalmers, David, 16 Berkeley Terrace.
1906. Chapman, Joseph, 24 Donaldson Street, Burnbank, Hamilton.
1904. Clark, William, 208 St. Vincent Street.
1903. Clarkson, William, Quarrymaster, Friar's Road, Lesmahagow.
1905. *Clough, C. T., M.A., H.M. Geological Survey Office, Edinburgh.
1900. *Cozens, Samuel F., Salem, Skelmorlie.
1891. Cowie, Charles R., Woodend, Partick.
1894. Dickson, Walter, Derwent, 30 Kelvinside Gardens, Kelvinside.
1883. *Dobbie, C. Lizars, 21 St. James' Street, Hillhead.
1905. Dobson, D. Bennett, 108 Douglas Street.
1907. Donald, W., Manufacturer, 60 Firhill Road.
1897. Donaldson, Archibald, 10 Abercromby Street.
1881. *Dougan, John, 69 Cadder Street, Pollokshields.
1887. Dow, William, 141 Stanmore Road, Mount Florida.
1907. Dowie, Archibald, 30 St. Vincent Place.
1895. Dron, R. W., A.M.I.C.E., 55 West Regent Street.
1906. Drummond, John, 35 High Street, Airdrie.
1906. Drylie, James, 45 Minard Road.
1883. Dunlop, Robert, Rosemount, Weirwood Park, Baillieston.
1901. Du Toit, Alex. L., Geological Commission, South African Museum, Cape Town, S.A.

Digitized by Google

Year of Election.

1906. Elliot, George B., 33 Millbrae Road, Langside.
1901. Faill, John, 7 Winton Drive, Kelvinside.
1900. Farrell, Richard C., C.E., 70 Wellington Street.
1898. Fergus, A. Freeland, M.D., 22 Blythswood Square.
1907.*Ferguson, Professor, M.A., LL.D., 13 Newton Place. [1906]
1895. Fingland, Mrs., Braehead Villa, Cathcart.
1897. Fingland, Samuel, Braehead Villa, Cathcart.
1895. Forbes, Alexander, Lecturer on Mining, 9 Midton Road, Ayr.
1901. Forsyth, William, c/o Sorley, 93 St. Vincent Street.
1898.*French, Thomas, 1 Kelvinside Terrace, Kelvinside.
1905. Frew, John, M.A., B.Sc., 17 Highbury Road.
1905. Fyfe, John William, 221 West George Street.
1901. Gale, William M., C.E., 18 Huntly Gardens, Kelvinside.
1892. Galloway, T. Lindsay, C.E., 175 West George Street.
1887. Gardner, John, 65 Great Clyde Street.
1901. Gemmell, E. W., 34 Carmichael Place, Langside.
1893. Gemmell, Matthew, 160 Bath Street.
1894.*Gilfillan, William, 129 St. Vincent Street.
1878.*Gilmour, Thomas, M.D., Port Ellen, Islay. [1873]
1895. Glen, Alexander, 25 Dumbreck Road.
1894. Goldie, James, 52 St. Enoch Square.
1900.*Graham, M. M., 21 Bath Street. [1877]
1904. Gray, John, 86 Minard Road, Crossmyloof.
1905.*Gregory, John Walter, D.Sc., F.R.S., Professor of Geology, Glasgow University. [1904]
1886. Guy, Robert, Writer, 120 West Regent Street.
1872. Hamilton, Archibald, C.E., Clyde Navigation Office, Robertson Street.
1876. Henderson, John, Ballochmorrie, Pinwherry, South Ayrshire.
1903. Hill, Alex., 302B St. Vincent Street.
1877. Hislop, G. R., F.C.S., F.R.S.E., Corporation Gas Works, Paisley.
1891. Hodge, William, 27 Montgomerie Drive, Kelvinside.
1906. Hoggan, John, Castlecary Station, Castlecary.
1897. Houston, Robert S., Meadowside, Glasgow Road, Paisley.
1901. Howie, George, Clydeside Cottage, Uddingston.
1894. Hubbard, John James, 9 Bute Mansions, Hillhead.
1894. Hubbard, Walter, Raglan, 9 Broomhill Avenue, Partick.

Digitized by Google

Year of Election.

1901. Hunter, William, Rosemount, Ledard Road, Langside.
1903. Hurll, Mark, Redholm, Temple.
1893. Innes, Peter, 5 Ibrox Place, Paisley Road West, Glasgow.
1890. Johnstone, Ronald H., C.E., 190 West George Street.
1901. Kemp, William, c/o Mrs. Brown, 1 Doune Quadrant, Kelvinside.
1870.*Ker, William, 1 High Windsor Terrace, Glasgow.
1890. Kidston, Robert, F.G.S., 12 Clarendon Place, Stirling.
1882. King, Hugh B., Kilwinning, Ayrshire.
1882. King, Robert C., C.A., Kilwinning, Ayrshire.
1894. Knight, Rev. G. A. Frank, M.A., F.R.S.E., St. Leonard's U.F. Church, Perth.
1892. Laird, Alexander, Cairleon, Kilmacolm.
1883. Laird, Andrew, C.E., 5 Northbank Terrace, Kelvinside.
1907. Laird, Archd. J., A.M.I.M.E., Kabulayathitti, Dharwaar District, Bombay Presidency, India.
1905. Lambie, James, M.B., L.F.P. & S., Kilwinning.
1901. Leighton, William, 36 Renfield Street.
1899. Lockhart, W. M., 151 Sword Street, Dennistoun, Glasgow.
1901. Lothian, A. Veitch, M.A., B.Sc., F.R.S.E., 11 Holborn Terrace.
1899. Lyle, William, 7 Beechwood Terrace, Shettleston.
1894. M'Ara, Alexander, 19 Dundonald Road, Kelvinside.
1866. M'Clelland, Andrew S., C.A., 115 St. Vincent Street.
1895. M'Connell, Alexander, C.E., c/o M'Alpine & Sons, 29 St. Vincent Place.
1896. M'Cowan, Donald, Dundashill House, Port Dundas, Glasgow.
1889. M'Creath, George W., M.E., 208 St. Vincent Street.
1904. M'Creath, William, M.I.C.E., 208 St. Vincent Street.
1901. M'Culloch, Andrew, 11 West Regent Street.
1901. M'Culloch, Rev. J. D., The Congregational Manse, Galston.
1884. M'Donald, A. B., C.E., 64 Cochrane Street.
1907. Macdougal, John, 37 Broomhill Drive.
1898. M'Gavin, Alexander, 23 Melrose Gardens, Kelvinside.
1894.*M'Gilvray, Robert A., 129 West Regent Street.
1867. M'Glashan, John, 114 Candleriggs.
1904. M'Intyre, Archd., 60 Cadzow Street, Hamilton.
1898. M'Kellar, John, 25 Kelvinside Terrace, South Kelvinside.
1903. MacKenzie, W. M., 7 Dryburgh Gardens.
1894. Mackie, John, M.E., Millview, Neilston.

Digitized by Google

Year of Election.

1901. MacKirdy, W. A. Scott, Birkwood Castle, Lesmahagow.
1877. Maclay, Bailie Wm., F.G.S., Thornwood, Langside.
1894. Maclay, James, 3 Woodlands Terrace.
1905. M'Lean, Alex., 466 St. George's Road.
1895. MacNair, Peter, F.R.S.E., Art Galleries and Museum, Kelvingrove.
1897.*M'Neil, Charles, South Cliff, Wemyss Bay.
1883. M'Whirr, John, 2 St. John's Road, Cathcart.
1887. Main, John, 24 Marlborough Avenue, Partick.
1900. Mann, Andrew C., c/o Wilkinson, 1207 Mount Royal Avenue, Montreal, Canada.
1902. Mann, Ludovic M'Lellan, F.S.A.(Scot.), 142 St. Vincent Street.
1874. Marshall, Robert, Grange Hill, Beith.
1902. Menzies, James R., 72 Lauderdale Gardens.
1881. Mitchell, G. A., 5 West Regent Street.
1899. Mitchell, J. M., Banker, Auchengray, Airdrie.
1904. Moore, Quintin, jun., 219 Greenhead Street.
1877. Moore, Robert T., B.Sc., C.E., 142 St. Vincent Street.
1885. More, Robert, 505 Sauchiehall Street.
1907. Morrison, D. A., 97 High Street, Paisley.
1902. Mort, Frederick, M.A., B.Sc., F.G.S., 116 York Drive, Hyndland.
1906. Mort, Spencer, Viewfield, Partickhill.
1889. Motherwell, A. B., Rosemount, Airdrie.
1900.*Muirhead, John, 13 St. John's Drive, Pollokshields.
1898. Munro, Alexander, 1 Colebrooke Place, Hillhead.
1894.*Murdoch, Robert, 91 Maxwell Road, Pollokshields.
1870.*Murray, David, LL.D., 169 West George Street.
1898. Murray, David, M.A., B.Sc., 7 Glebe Road, Kilmarnock.
1891. Neilson, James, Milnbank House, Dennistoun.
1894.*Neilson, James, 116 Bishop Street, Port Dundas.
1907. Nicol, J. Hall, Builder and Contractor, Hamilton.
1906. Nicolson, David, School-house, Neilston.
1898. Nimmo, David, 17 Duke Street, Hamilton.
1894. Niven, Thomas Ogilvie, 131 West Regent Street.
1897.*Orr, John, 12 Newhall Terrace, Glasgow. [1869]
1905. Paisley, John, Jeweller, 25 Gordon Street.
1905. Paton, Robert K., 17 Stanmore Road, Mount Florida.

Digitized by Google

Year of Election.

1875. Pearson, David, Crannich, Woodend Drive, Jordanhill.
1891. Pollock, Arthur, Kirkland, Bonhill, Dumbartonshire.
1873. Rankine, David, C.E., 238 West George Street.
1880. Reid, James A., M'Grigor, Donald & Co., 172 St. Vincent Street.
1903. Reid, William, 133 Finlay Drive, Dennistoun.
1874. Renwick, John, 49 Jamaica Street.
1902. Reoch, James W., 22 Montgomerie Street, Kelvinside.
1875.*Rottenburg, Paul, LL.D., Holmhurst, Dowanhill Gardens, Glasgow.
1904. Rutherford, James, M.E., 35 Blythswood Drive.
1898. Scott, Colonel, Bellside, Cleland.
1893. Sexton, Professor A. Humboldt, Technical College, Montrose Street.
1897. Shanks, Archd., Mount Pleasant, Dalry.
1891.*Sharp, John Grant, 127 Great Hamilton Street.
1889. Simpson, Rev. Alex., B.A., B.Sc., F.G.S., 28 Myrtle Park, Crosshill.
1888. Sinclair, Thomas, 206 New Dalmarnock Road.
1887. Sinclair, William, 45 Oswald Street.
1889. Sloan, Samuel, M.D., 5 Somerset Place, Sauchiehall Street.
1865. Smith, John, Dykes, Dalry.
1901. Sneddon, Richard, 60 Pitt Street, Newton, Cambuslang.
1887.*Somerville, Rev. James E., B.D., Castellar, Crieff. [1887]
1905.*Somerville, Joseph, 40 Montgomerie Street, North Kelvinside. [1871]
1899. Sommerville, Wm., Carronben, Buchanan Drive, Cambuslang.
1902. Spencer, James, jun., 7 Kelvingrove Terrace.
1896. Stark, James, 13 Princes Gardens, Partick.
1881. Steel, James, 391 St. George's Road.
1884. Steele, Robert Innes, 3 Nithsdale Place, Pollokshields.
1901. Stewart, Andrew, Lairdsland School, Kirkintilloch.
1906. Stewart, Robert D., Belinda Cottage, Shettleston.
1878. Stewart, Thomas, St. George's Chambers, Cape Town, South Africa.
1891. Stirling, David, 10 Cook Street, Glasgow.
1902. Sykes, William, 24 Hamilton Park Terrace, Hillhead.
1897. Thomson, Henry, 10 Princes Square, Strathbungo.

Digitized by Google

Year of Election.

1906.*Tullis, James T., Aytoun House, Sydenham Road, Dowanhill. [1885]
1906. Tyrrell, G. W., Geological Department, Glasgow University.
1907. Waddell, A. W., M.E., 4 Eton Terrace, Hillhead.
1901. Wight, E. Hall, 150 Hope Street.
1866. Wight, John, C.A., 150 Hope Street.
1881. Wotherspoon, David, 982 Argyle Street.
1902. Young, Archibald A., 2 Parkgrove Terrace, West.
1896.*Young, James, jun., Carlaeon, Bearsden.
1899. Young, Robert S., 56 Mitchell Street.

Note.—Asterisks indicate Life Members. A year in brackets after a name indicates the date of joining as an ordinary member.

Digitized by Google

Digitized by Google

TRANSACTIONS

OF THE

GEOLOGICAL SOCIETY OF GLASGOW.

No. X.—The Stratigraphy of the Arden Basin.

By R. G. Carruthers, H.M. Geol. Survey, and E. M. Anderson, M.A., B.Sc., H.M. Geol. Survey.*

[Read 14th February, 1907.]

By the term Arden basin we mean the elongated synclinal area, whose axis extends in an easterly or east-south-easterly direction from Barrhead as far as the White Cart. It is bounded on the south by the large upthrow fault, which brings in volcanic rocks of earlier Carboniferous date. On the other side its limits are not so clearly defined. To the north-east the inward or southerly dip extends, in spite of minor faulting, as far as the great fault, which lets down the Coal Measures at Strathbungo. Round the margins of this basin are areas of the underlying Coal-bearing group of the Carboniferous Limestone series, known as the Edge or Possil Coals, but all the central part is occupied by strata of the Upper Limestone group. These include strata ranging from the Cowglen or Index Limestone, which forms the base of the group, to some distance above the Arden Limestone. The strata above the latter horizon are shown on the old Survey map (sheet 30, 1-inch) as belonging to the Millstone Grit. But as a higher seam, namely, the Castlecary Limestone, is now adopted as the lower limit of the Millstone Grit, these strata are now included in the Upper Limestone series.

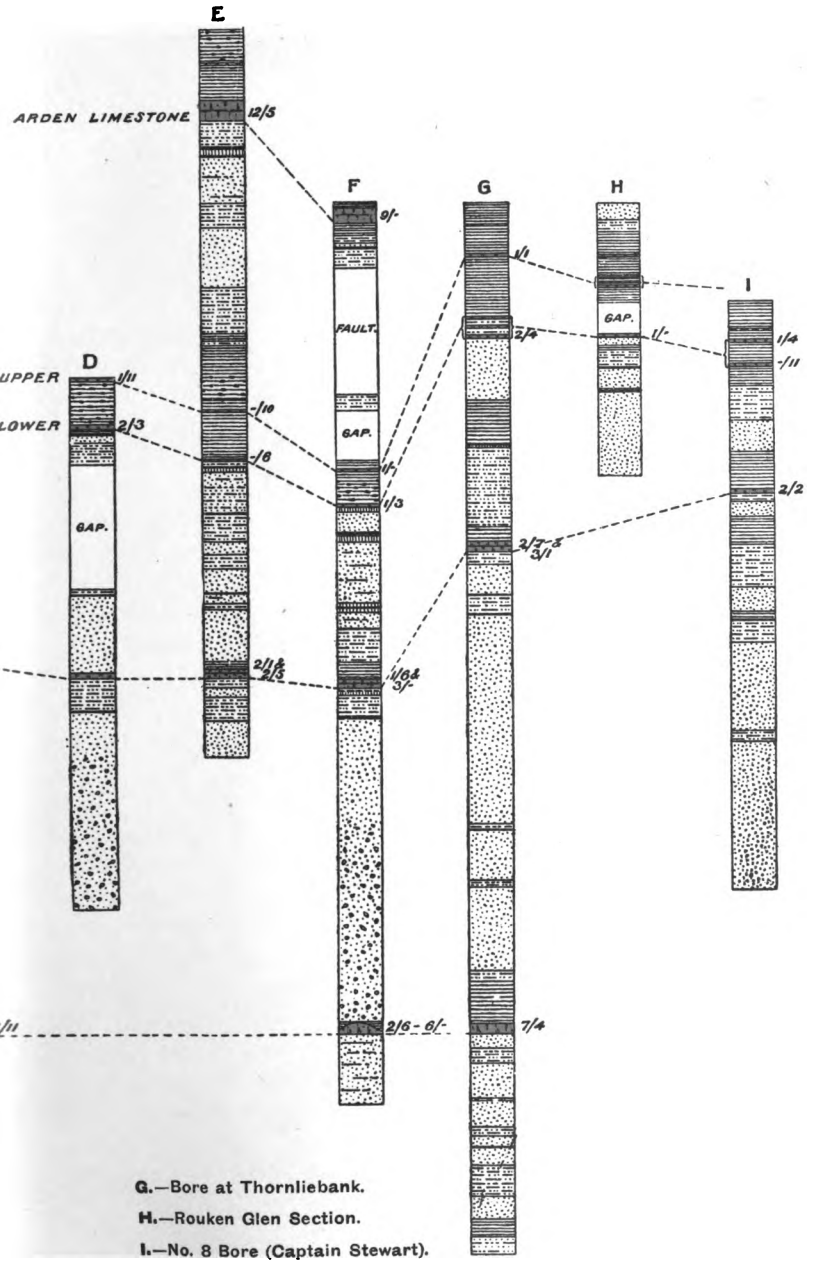
* Communicated by permission of the Director of the Geological Survey of Great Britain.

Digitized by Google

Before beginning the stratigraphical part of our paper reference may be made to the work of previous investigators. In the "Statistical Account of Scotland," vol. 7, published in 1845, under the heading of the parish of Eastwood, reference is made to the Arden and Cowglen Limestones, and it is recognised that they are separate seams. Nothing, however, is said about the Orchard Limestone, though the Giffnock Sandstone was already worked in two quarries. The eastern part of the ground which is the subject of our description was surveyed in 1868 by Professor (then Mr.) E. Hull and by Professor (then Mr.) James Geikie, at that time attached to the Survey. The Orchard Limestone was now being worked, and it was supposed that there were three beds of limestone in the Upper Limestone group—the Cowglen, Orchard, and Arden Limestones—in ascending order, the position of the Giffnock Sandstone being between the first and second. In February, 1869, a paper "On the Carboniferous Sections of the Levern Valley, Renfrewshire,"* was read to this Society by Mr. Hugh M'Phail. In this paper he shows the important part played by the thick pebbly sandstone overlying the Index or Cowglen Limestone in the stratigraphy of the district. He identifies the limestone found in the reservoir south of the Waukmill Glen, rightly, as we think, with the Cowglen, and he records the presence of the Lyoncross Limestone in an intermediate position between it and the Arden horizon. He also correctly interprets the section in the Nitshill railway cutting, identifying the limestone there with the Lyoncross, and points out the necessity of supposing that there must be a large strike fault running along the north-western part of the basin. According to our present view, however, he fell into one mistake. Knowing only of one intermediate limestone between the Cowglen and the Arden horizons in the Waukmill Glen section, and of one limestone between the same two horizons near Giffnock, he naturally supposed that the two were the same. He thus correlated the Lyoncross with the Orchard Limestone, while the limestone lying beneath the Giffnock Sandstone he regarded, in common with the Geological Survey, as being the Cowglen. The western part of the district under consideration was surveyed by the officers of the Survey in 1870.

* *Glas. Geol. Soc. Trans.*, vol. iii., p. 254.

Digitized by Google



G.—Bore at Thornliebank.

H.—Rouken Glen Section.

I.—No. 8 Bore (Captain Stewart).

Digitized by Google

Digitized by Google

They mapped the limestone in the reservoir as the Cowglen, but they avoided expressing any opinion as to the correlation of the Lyoncross. The 6-inch Survey maps, which include the Arden basin, were published between 1869 and 1875; the 1-inch sheet to the south (No. 22) was published in 1870; the 1-inch sheet which includes the northern part of the basin (No. 30) was not published till 1878.

In December, 1881, the late Captain Stewart of Williamwood read his classical paper to this Society, entitled "Notes on the Limestones in the Parishes of Cathcart and Eastwood, Renfrewshire."* In this he clearly showed, from bores sunk at Orchard and beside the Hole Burn S.E. of Pollokshaws, as well as at other places, that the limestone immediately underlying the Giffnock Sandstone was not, as had been supposed, the Cowglen Limestone, but a separate band lying about 40 fathoms above that horizon. He thus determined the presence of four limestones in the Upper Limestone series of this district, namely, the Cowglen, Hole Burn, Orchard, and Arden, the Giffnock Sandstone lying immediately above the Hole Burn Limestone. Captain Stewart also showed that both the Hole Burn and Orchard Limestones are present in the southern part of the basin. He believed that the latter occurred in some places in two bands, one of which it was which was exposed in the Rouken Glen just below Thornliebank House. His paper was accompanied by a geological map, which added a great deal to the previous knowledge of the district, and to which further reference will be made in the sequel.

In December, 1889, the late Mr. Murdoch contributed a few notes on the journal of a bore put down for water at Thornliebank, which was published, together with Mr. Murdoch's interpretation, in the *Transactions* of this Society.† In a paper recently published‡ Mr. Macnair puts forward the view that there are three instead of two limestone horizons between the Cowglen and the Arden. The extra one, it is unnecessary to remind the Society, is named by him the Rouken Glen Lime-

* *Glas. Geol. Soc. Trans.*, vol. vii., p. 158.

† "Journal of a Bore put down for Water at Thornliebank, Renfrewshire. With notes on the strata."—*Glas. Geol. Soc. Trans.*, vol. ix., p. 207.

‡ "The Geology of the Rouken Glen and its Neighbourhood."—*Glas. Geol. Soc. Trans.*, vol. xii., p. 362.

Digitized by Google

stone, which he supposes to come above the Orchard, and to be the one which occurs in the Rouken Glen, and also at Thornliebank. The result of our joint revision of the area has been, in our opinion, to confirm the view previously adopted by Captain Stewart, and also to establish the identity of the Hole Burn Limestone with the Lyoncross.

In an investigation of this nature it is desirable to use as a datum line some definite zone whose course can be accurately traced throughout the district. In the present case a satisfactory line is afforded by the Cowglen or Index Limestone. Occurring, as it does, just above the group of the Possil Coals, this limestone has been proved at several points in the district through mining operations, while it is likewise exposed in many natural and artificial sections, where, as will be seen later, the peculiar lithological characters of the accompanying strata allow of a ready identification of this horizon in the field. We propose to follow the outcrop of this limestone round the basin, using the data so obtained to fix the position of the various members of the Upper Limestone group.

We shall first describe the succession from the Cowglen Limestone up to the Orchard, as met with round Giffnock and Orchard. In some respects this district presents what we may take as the type section for the area with which we are dealing. The lower part of the succession is proved by the journal of a bore which was put down close to the Giffnock Colliery (see A, Plate VII.). The same strata were afterwards passed through in deepening the shaft.

The Cowglen Limestone in this bore has a thickness of 5 feet 10 inches, and has 4 inches of coal below it, and separated from it by only 2 inches of limy blaes. It is in one post, and above it is a thickness of 32 feet of blaes with ironstone nodules. Above the blaes comes a post of sandstone, which is succeeded by 2 feet 2 inches of "hard, limy fakes" at a distance of 13 fathoms above the Cowglen. This is the equivalent of the local limestone seam, which is described at about the same distance above the Cowglen Limestone in several of Captain Stewart's bores. Then comes more sandstone with a little blaes, and no fewer than four thin seams of coal. Above the highest of these comes an uninterrupted post of 13 fathoms of sandstone; parts of this are described as coarse, and have

Digitized by Google

been picked out in the vertical section. Just above the sandstone is a thin coal. A short distance further up is the coal which was formerly worked at Giffnock Colliery. It is 3 feet thick, but here at least it is poor in quality. Two fathoms above it comes the Hole Burn Limestone, and we may, in the meantime, refer to the coal seam as the Hole Burn Coal. The limestone itself is in two leaves, 3 feet 3 inches and 1 foot 4 inches in thickness, and separated by 1 foot 6 inches of dark blaes. Here the section as given in the bore journal ceases, but in an old shallow shaft, just a little to the north of the present Giffnock Colliery buildings, the upper band of limestone is seen to be separated by 4 feet of blaes from the base of the Giffnock Sandstone.

The points we wish to emphasise in the section so far considered are—

(1) The Cowglen Limestone is in a single post, and has no coal below it worth speaking of. Above it are more than 5 fathoms of blaes.

(2) From above this blaes to not far below the succeeding Hole Burn Limestone comes a series in which sandstone plays by far the largest part. Parts of this sandstone are of a coarse and gritty character.

(3) Underlying the Hole Burn Limestone, and about 2 fathoms below it at Giffnock, is a coal of moderate thickness. The limestone itself is in two parts, close together, and separated from the overlying sandstone by only about 4 feet of blaes.

As we proceed, each one of these points will be seen to be of importance for purposes of correlation.

The remainder of the section in this district is given by the Orchard bore (No. 2 in Captain Stewart's paper, before referred to),* together with the numerous quarries which have been opened in the Giffnock Sandstone and the former workings in the Orchard Cement.

Reckoned up to the position of the Moor Rock Coal, the sandstone quarried at Giffnock has sometimes a thickness of 60 feet. The term Giffnock Sandstone, however, is sometimes restricted to the lower part of this thickness, which is otherwise known

* Captain Stewart presented the complete journals of all the bores referred to in his paper to the library of the Society.

Digitized by Google

as the Liver Rock. For the purposes of this paper we shall use the term Giffnock Sandstone in a broad sense to include all the sandstone between the Hole Burn Limestone and the Orchard Cement, whether above or below the position of the Moor Rock Coal. The coal referred to is best exposed in the New Braidbar Quarry, where it is 14 inches in thickness. It is shown to be inconstant by the fact that neither in Williamwood Quarry to the south-east nor in the nearest quarries to the north-west, in which its position is exposed, is there any sign of it. It even dies out to the east in New Braidbar Quarry itself. Neither is there any mention of it in the Orchard bore. This bore shows the total thickness from the base of the Orchard Cement to the blaes above the Hole Burn Limestone to be about 27 fathoms; this distance is almost entirely occupied by sandstone, but there is a 7-inch coal about 2 fathoms below the cement. There is also a thin coal just immediately below the cement, separated from it by only an inch or two of blaes, and formerly mined along with it. This is evidently a different seam from the one met with in the bore, and we thus see that three horizons of thin coals occur in the interval between the Hole Burn Limestone and the Orchard Cement. We shall find this fact also useful for purposes of correlation.

Coming now to the Orchard Cement Limestone, its thickness at Orchard itself is 2 feet, and 15 feet of blaes above it were exposed in the old workings. This, however, does not represent the total thickness of the Orchard blaes, which is best seen in Bore No. 1A of Captain Stewart, which was put down to prove the limestone about a mile S.E. of Orchard. In this bore there is a thickness of 7 fathoms of "dark fakes" above the limestone, and in this case the term evidently refers to blaes. Above these "fakes" comes a "kingle," 1 foot 1 inch, and this we take to be an upper band of limestone. We shall find further evidence as we proceed of the presence of this upper band a few fathoms above the band of limestone which was first recognised, and we shall distinguish the two in future by the terms Lower and Upper Orchard Limestone. The existence of the Upper Orchard, as before remarked, was known to Captain Stewart.

Digitized by Google

Above the Upper Orchard Limestone the section, as definitely known in this district, ceases. In our table of vertical sections (Plate VII.) we have indicated what we suppose is the completion of the section up to the Arden Limestone. We do not think that any further beds of limestone occur in this interval. The Upper Orchard is, we believe, succeeded by a further thickness of blaes, and above this is mostly sandstone till we come to the one or two thin coals which underlie the Arden Limestone. The thickness from the Upper Orchard to the Arden we take in round numbers to be about 25 fathoms, and the total thickness from the Cowglen Limestone up to the Arden is about 90 fathoms. Our reasons for these conclusions will become apparent as we proceed. The figures here given are in agreement with those indicated in the tabular comparison of bores drawn up by Captain Stewart.

At the old mining district of Nitshill, on the north side of the basin, a very good section of the beds overlying the Cowglen Limestone is seen in the railway cutting east of the station (B, Plate VII.). The strata dip uniformly south-east at angles of from 15 degs. to 25 degs., and, with the exception of a large fault terminating the section on the east, present an unbroken succession. The fault referred to, as noticed by Mr. M'Phail, was at one time well seen in the cutting, but is now concealed. It runs in a south-westerly direction to Barrhead, having a downthrow to the south-east of from 20 to 60 fathoms.

The succession, as measured in the cutting, is in descending order—

These Sandstones are all fine grained.
- White and grey sandstones, with thick blaes partings, 21 ft.
- Broken yellow and white flaggy sandstone, 17 ft.; blaes parting, 6 ins.
- Yellow and white sandstone, in good beds, 27 ft.

Dark blue shale, with small ironstone nodules, 0-3 ft.

Hole Burn Seams.
- Cement limestone, cement, 1 ft. 4 ins., blaes parting, 0-9 in., cement, 1 ft. 7 ins., } 3 ft. 6 ins.
- Flaggy yellow and white sandstone, 21 ft.; coal, 1 ft. 4 ins. to 2 ft.

Massive sandstone, coarse and gritty at base, 25 ft.

Massive soft grit, 31 ft.

Fake and blaes (with a band of sandstone and fireclay, 7 ft. 6 ins.), about 25 ft.

Massive grit, with pebbly bands, 40 ft. seen.

Digitized by Google

The cement has a bright ochreous weathering, rendering it a conspicuous object in the cutting. It is grey on a fresh surface, and contains small brachiopods and crinoid stems, though not in any great abundance. No fossils, however, were observed in the overlying blaes.

The coal was worked by Mr. Kirkwood, of Darnley, down to the large S.W. fault; the old workings, with some of the old wooden props for the roof, can be seen on the south wall of the cutting.

The massive grits in the lower part of the section are coarse, and full of strings of white quartz pebbles. They are slightly ferruginous and soft, disintegrating readily on exposure. We hope to show that these grits preserve their character throughout the basin.

The Cowglen Limestone, though not seen in the cutting, must immediately underlie the base of this coarse grit; for a few yards to the north of the westerly railway bridge an old pit was sunk 15 fathoms to the Boghouse Coal—a seam lying from 18 to 20 fathoms below that limestone. As the mining evidence in this locality shows the absence of any fault which would affect the strata in the cutting, the crop of the limestone may be laid down on the map with some accuracy.

Leaving the cutting and proceeding in a south-westerly direction, we find within half a mile a good escarpment of the pebbly grit west of Wardhill Farm. Mr. M'Phail observes that at this spot on the ridge a pit was sunk through the grit reaching the Cowglen Limestone, here 10 feet thick, at a depth of 14 fathoms.

A little further south, just beyond Parkhouse and near the main road to Barrhead, a disused sandstone quarry is seen in the upper bands of the pebbly grit. Overlying the sandstone occurs a coal about 1 foot 6 inches thick, which was worked for a short distance inwards, till cut off by a large downthrow fault (a continuation of the one in the Nitshill railway cutting). According to Mr. M'Phail, the coal was also found in a well at Parkhouse, close by.

In the quarry a bore was put down from the coal outcrop (C, Plate VII.), and, after passing through 30 fathoms of sandstone, went through the Cowglen Limestone, and proceeded well down into the Possil Coal series beneath.

Digitized by Google

Comparing the sections, it is seen that the Parkhouse Coal is the same as that worked in the Nitshill cutting, 21 feet below the cement, *i.e.*, it is the Hole Burn seam. At Barrhead a continuous escarpment of the pebbly grit is seen, in which several old quarries have been opened to the north-east of the town. As noted by Mr. M'Phail, most of the old part of Barrhead is built on the continuation of this ridge, while the Cowglen Limestone underlying the grit was struck in the foundations of the Arthurlie Biscuit Factory, in the centre of the town.

South and south-east of Barrhead a number of most interesting sections are seen. In the goods yards, just west of Upper Arthurlie Bleach Works, there is an exposure of the pebbly grit, dipping S.E., while in the Kirkton Burn, to the south, the grit is again seen lying with a sharp junction line on a series of fine-grained, flaggy sandstones, both dipping to the N.W., the strata thus forming a small basin whose extent has been fully proved by the workings of the Barrhead Main Coal. This seam, formed by the coalescence of two smaller ones (some 7 feet apart at Nitshill), lies about 20 fathoms below the Cowglen Limestone, and has been extensively wrought round Barrhead in the past. The crop workings are still visible in the Kirkton Burn. West of the burn is a deep cutting in a new branch of the Caledonian Railway connecting Barrhead with the Ardrossan line. The section is an important one, as it gives a clear idea of the strata associated with the Cowglen Limestone (see Fig. 1). At the west end of the cutting an anticlinal fold is seen—the complement of the syncline just described. The lowest beds are white sandstones, with numerous grey fireclay partings, with a bed full of irregular ironstone nodules on the top. Overlying this is a streak of cannel coal with fish remains, followed by blaes, with partings of hard, ferruginous sandstone. This, again, is overlain by sandstone with two thin coals, on which rests a succession of massive, fine-grained, yellow and white sandstones 33 feet thick, with much ferruginous staining on the outside. Above this sandstone is seen the great grit, the line of junction indicating unconformability or local erosion. Sometimes the grit rests directly on the fine-grained sandstones, but usually

Digitized by Google

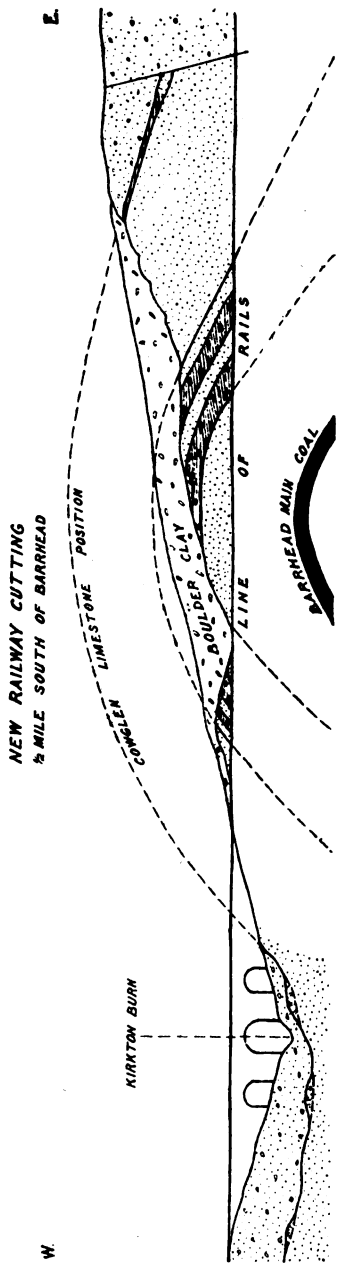


Fig. 1.

Digitized by Google

there is a parting of blue blaes with ironstone nodules, while at two places close to a fault with a downthrow to the east, crossing the cutting at the small plantation, it lies on a lenticular limestone band. This limestone—a thickness of 2 feet is visible—is ochreous, very hard, somewhat dolomitic, and is almost destitute of fossils. Pebbles both of the limestone and the ironstone nodules of the associated blaes occur at the base of the grit. That this lenticular limestone is the Cowglen is shown not only by its occurrence at the base of the grit, as at Nitshill, Wardlaw, Parkhouse, and the biscuit factory, but by its distance above the Barrhead Main Coal, which can be readily calculated, since the coal has been worked all through the immediate district, and its outcrop is seen in the Kirkton Burn close by. The fault just mentioned as crossing the cutting has been proved at several points in the workings to have a downthrow of 6 fathoms.

From this evidence we may reasonably infer that the erosive junction between the great grit and the underlying fine-grained, flaggy sandstones, as seen in the Kirkton Burn, is on the horizon of the Cowglen Limestone; in fact, a note on the old Survey 6-inch map records "limestone 2 feet" in the burn at this spot. Part of the section is now obscured, and the limestone is no longer visible here. The erosive junction is again seen in a streamlet joining the Kirkton Burn just south of the Upper Arthurlie Bleach Works.

The great grit occupies the remainder of the railway cutting, which furnishes an excellent section of this important zone.

With the exception of a short gap, the section is continued eastwards into Springfield Glen (see vertical section, D, Plate VII.). At the head of the glen, south of the new railway bridge, the pebbly grit overlying the Cowglen horizon is well shown in a cliff section. It becomes finer-grained in its upper portion, as at Nitshill, and is overlain north of the bridge by a workable coal. Three old "ingoing eyes" to this coal are seen on the west side of the glen. Above the coal workings 16 feet of faky sandstones supervene, overlain by a band of cement limestone, divided into two seams by a thin parting of blaes, the lower bed being 2 feet 5 inches thick and the upper

Digitized by Google

one 9 inches. Immediately above the cement come a series of fine-grained faky sandstones, with a coal streak about 40 feet above the cement. The identity of this glen section with that in the Nitshill railway cutting is obvious. The junction of the fine-grained, faky sandstones with the underlying cement is marked by a thin pebbly band about an inch thick, and there would appear to have been some local erosion here also, as one or two deeply-weathered pebbles of the cement were found in the band.

The section ends immediately beyond the coal streak 40 feet above the cement, but a short distance further down the stream, in a bore for water at the South Arthurlie Print Works, two thin bands of cement were found separated by 27 feet of blaes. The section, which is shown in the upper part of D, reads as follows:—

	Feet.	Inches.
Depth of well,	13	0
Cement *limestone*,	1	11
Blaes, limy and with lime balls in upper part,	27	0
Cement *limestone*,	2	3
Dark limy blaes,	2	5
Coal,	1	7
Hard sandstone,	3	0
Fakes and a little blaes,	12	2
Total,	64	8

Unless some unknown fault exists, these cements lie about 120 feet above the one seen further up the glen, which has been correlated with that in the Nitshill cutting, and they have been shown in that position in the vertical section D. Eastwards along the railway another cutting is soon reached half a mile west of Lyoncross, which furnishes evidence of great interest. This locality is near the great E. and W. boundary fault, which lets down the Lower Carboniferous volcanic rocks against the Carboniferous Limestone series. Indeed, the position of the fault is indicated in the cutting (see Fig. 2). All the strata dip N. or N.W. The pebbly grit, which is the highest bed exposed, occurs at the west end of the cutting. It is worthy of note that the grit is here pierced by a remarkable whinstone dyke full of foreign boulders, such as limestone, sandstone, blaes, and various types of igneous rocks, apparently derived from a crush breccia in the boundary fault. At

Digitized by Google

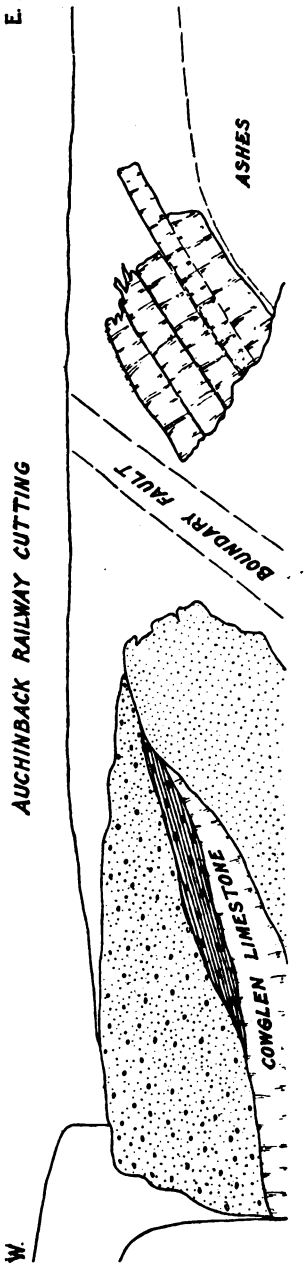


Fig. 2

Digitized by Google

several other places near Barrhead small whinstone dykes may be noticed invading the sediments in the neighbourhood of the great fault.

Under the grit and on both sides of the railway bridge is seen a very hard, ochreous, grey weathering limestone, with very few fossils. It is very lenticular, and is usually overlaid by a thickness of 2 or 3 feet of blue blaes, with ironstone nodules. The limestone rests on a series of hard, fine-grained, flaggy, white sandstones, with much ferruginous staining. The junction of the pebbly grit with the underlying rocks is highly irregular. On the south side of the railway bridge it rests in turn on the limestone, the blaes with ironstone balls, and on the fine-grained sandstones below; pebbles of ironstone and limestone are found at the base of the grit. It will be seen that the section here is identical with that exposed in the deep cutting south of Barrhead; there can be no doubt that we are here dealing with another exposure of the Cowglen Limestone and the very characteristic strata associated with it.

The underlying flaggy sandstones show signs of great disturbance, and are brought against a limestone, weathering a pale blue colour, of a very different character from those already described. The band is 13 feet thick, the upper half having several partings of limy blaes, while at the base is a post of good, hard limestone 4 feet 8 inches thick, divided by half an inch of blaes. All the limestone is fossiliferous, small brachiopods being especially abundant, there being also small Zaphrentid corals, *Lithostrotion junceum*, and other forms, besides an abundance of crinoid stems. Both lithologically and palæontologically this rock bears a strong resemblance to the Thorntonhall Limestone, so well seen some 3 miles to the east. A little digging in the embankment showed that, like that limestone, the one in the cutting rests on ashy blaes, quickly followed by red, yellow, and green tuffs, which in turn are seen to rest on lavas further along the cutting. In fact, the boundary fault runs between the two limestones seen in the cutting. As calculated from other data in the district, the throw of this fault must be over 250 fathoms at this spot.

The Cowglen Limestone is again exposed in a small quarry

Digitized by Google

200 yards east of Auchinback, and just north of the filter bed. The limestone here is somewhat crystalline in its upper part. In the quarry it is overlain by the pebbly grit, while under the limestone come the fine-grained, flaggy sandstones exactly as in previous sections.

Before describing other sections we may now summarise the evidence advanced in the foregoing pages. It may be regarded as established beyond doubt—

(1) That the Cowglen Limestone of the Barrhead district is underlain by 30-40 feet of fine-grained, flaggy sandstones.

(2) That the limestone itself is lenticular in character along the south side of the basin, owing to erosion and irregular deposition.

(3) That it is overlaid by a massive pebbly grit up to 30 fathoms thick, which is succeeded by a coal seam averaging 1 foot 6 inches in thickness (the Hole Burn seam).

(4) That about 16 feet above the coal comes a cement limestone averaging 3 feet 6 inches in thickness, having a thin parting of blaes in the middle.

(5) That the succeeding beds are fine-grained, flaggy sandstones, and that a thick mass of blaes with two thin cement bands occurs, probably, but not certainly, about 16 fathoms above the thick cement.

About 100 yards N.E. of the filter bed quarry is a small ravine, in which a coal occurs in flaggy sandstones, having a cement limestone 14 feet above it. Both coal and cement were at one time worked, the coal being known as the Lyoncross seam, from the farm of that name close by. It was 1 foot 4 inches in thickness, and of good quality; according to Mr. M'Phail, the workings were continuous with those in the Waukmill Glen, half a mile to the east. We hope to show, from the evidence to be brought forward in the sequel, that the Lyoncross seams of coal and cement are identical with those seen in the Nitshill railway cutting at Parkhouse and at Springfield Glen. From the mapping, it is evident that a large fault must intervene between the Lyoncross seam in the small dingle and the Cowglen Limestone exposed in the filter bed quarry. It is interesting to note that this fault has been proved in an open cast working for cement at Little Auchinback,

Digitized by Google

half a mile to the N.W., to which reference will presently be made.

Not far to the east the well-known section in the Waukmill Glen occurs. We hope to show that, with the exception of two short gaps, there is here displayed a complete section of the Upper Limestone group, from the Cowglen up to the Arden Limestone, inclusive (see vertical section, F, Plate VII.). The dip of the strata in the upper part of the glen is steadily to the N., veering round to N.W. Consequently, the lowest bed crops out at the head of the glen and in the reservoir beyond.

Mr. M'Phail noticed that the Cowglen Limestone cropped out in the reservoir, where it was overlaid by the "thick-bedded sandstones." During the original Survey of this area Professor Hall, in noticing this fact, gives a section in his notebook, showing that, under the water tower in the reservoir, the limestone—here only 2 feet 6 inches thick—was overlain by a foot or so of dark blaes, succeeded by the massive pebbly grit. This particular section is now under water, but a similar one is seen in the quarry at the N.E. end of the reservoir, where nearly 40 feet of the fine-grained, flaggy sandstones under the limestone are seen. The limestone itself is 6 feet thick, the upper part deeply weathered to an ochreous clay, though the lower post, as is usual in these limestones, is of better quality and but slightly weathered. The difference in thickness of the limestone, as observed at the E. and W. ends of the reservoir, is, of course, in accordance with the lenticular nature of the Cowglen band, along the south crop, to which reference has already been made. On the west side of the quarry a small fault, well seen when the water is low, brings down the pebbly grit against the limestone.

Returning to the west end of the reservoir, and following the course of the Brock Burn as it flows down into the Waukmill Glen, the first section noticed is a fine exposure of the great grit, the beds dipping at an angle of 16 degs. to the north. The upper portions are, as usual, fine-grained and with some faky partings. Above are seen the workings of the Lyoncross Coal, and 14 feet higher up comes the Lyoncross Cement. The latter, like the limestone occupying a similar position at Nitshill and Springfield, which at Nitshill has been correlated with

Digitized by Google

the Hole Burn Limestone, is divided into two beds by a thin parting of blaes. The lower post, 2 feet 4 inches thick, is the only one used for commercial purposes, the upper post, 1 foot thick, being of poor quality. Above the cement, as is well known to many members of the Society, comes a thick mass of blaes, containing bands of marine fossils in an excellent state of preservation. This feature, it will be noticed, is not seen in the sections at Springfield and Nitshill, although a comparison of these sections must, we think, leave no doubt as to their identity.

Above the Lyoncross Cement is a succession of 90 feet of strata, chiefly consisting, with the exception of the fossiliferous blaes just mentioned, of flaggy sandstones, having two coal streaks about equal distances apart. The best post of sandstone is at the top, and on it lies a band of cement limestone 1 foot in thickness; a short working was made in this cement, but the seam proved too thin, though of better quality than the Lyoncross band. Overlying it are seen 10 feet of limy blaes, in which, as far as we know, there are no fossils. Immediately beyond this point, just where the fence crosses the glen, a second cement band, 9 inches to 1 foot in thickness, was found by us on clearing away the surface soil. It lies about 16 feet above the lower band. It will be seen that the position of this thick mass of blaes, with the two thin cement bands, agrees well with that found in the boring at the South Arthurlie Print Works, and which was provisionally ascribed to a horizon about 100 feet above the Lyoncross Cement seen in Springfield Glen.

After a short gap the section is continued further down the stream, the dip of the strata swinging round to the N.W. The first beds seen are dark fakes and blaes exposed just above the small bridge crossing the burn. Immediately beyond the footbridge these are truncated by a fault, whose throw may be calculated, from workings in the Arden Limestone at this spot, to be about 12 fathoms.

Beyond the fault appear the flaggy sandstones below the Arden Coal, followed by the coal and a thin band of sandstone, succeeded by a mass of limy blaes passing up into the Arden Limestone. These strata, crossing the stream where it

Digitized by Google

bends to the N.W., are well known, and need no detailed description here.

The thick mass of shale containing two thin cement bands 16 feet apart may be calculated, from the field evidence, to lie about 25 fathoms below the Arden Limestone, unless a fault crosses the stream through the short gap in the section just above the bridge. There is no evidence for such a fault in the extensive quarries in the Arden Limestone in this district, nor is one recorded from the workings of the Lyoncross Coal to the west. On the other hand, confirmatory evidence of the position of these two cement bands relatively to the Arden Limestone and the Lyoncross Cement may be obtained from a bore put down half a mile to the N.W., about a quarter of a mile S.E. of Parkhouse (Salterland No. 2 Bore, see vertical section E, Plate VII.). This bore starts 25 fathoms above the Arden Limestone. After passing through that seam (12½ feet thick) and the coal beneath, it went through a series of fakes and sandstones, and, at a depth of 21 fathoms below the Arden, entered a mass of limy blaes 11½ fathoms thick, having two thin cement bands 10 inches and 6 inches thick—one in the middle and the other at the base of the blaes. Further down the bore passed through another series of fakes and sandstones with two thin coals, as at Waukmill Glen, underlain by another cement 4 feet 7 inches thick, with a parting of blaes, and terminating just beyond a coal 24 feet beneath. A comparison of this bore with the section in Waukmill Glen proves, in our opinion, the identity of the thick mass of blaes and two thin cement bands seen in the two sections. Further, the two thin coals below are similar to those seen in the Waukmill Glen above the Lyoncross Cement. An interesting point of difference between the sections is that below the lower coal streak a solid post of sandstone 32 feet thick was met with in the boring, while at the same position in the Waukmill Glen only blaes, with fakes and sandstone in the upper portion, are seen. Again, in the bore the cement, 4 feet 7 inches thick, agrees with the Lyoncross Cement, and the coal, 24 feet below the cement, occupies the position of the Lyoncross Coal. Although in the bore this coal was only recorded as 2 inches thick, it must be remembered that it was met with over 80 fathoms

Digitized by Google

down, a depth at which the thickness of a coal seam, always liable to be underestimated in a chisel boring, would be easily miscalculated.

Before leaving the Barrhead district, it may be as well to record some additional facts which throw light on the distribution of the various members of the Upper Limestone group in other parts of this district.

The Arden Limestone was worked by Mr. Macara a few years ago on the west side of the Free Church manse at Barrhead, in continuation of the Dovecothall workings mentioned by Mr. M'Phail. The limestone here was highly inclined to the S.E., and the workings were brought to an end by a downthrow fault, shifting the crop of the limestone further to the south. It was again found near the lodge at Arthurlie House, in a drain section which cut through the upper parts of the limestone and the overlying blaes. Lithologically, the stone was the same as that seen in the Darnley Quarries, and showed none of the ochreous weathering seen in the cements below this position.

A cement limestone of excellent quality was also worked by Mr. Macara south of Little Auchinback. The journal of shallow bores and other information in the vicinity show that this cement is in all probability the lower one of the two thin upper bands found in the No. 2 Salterland Bore, and seen in the trial workings in the Waukmill Glen. Mr. Brown, the manager of the works at Waukmill Glen, identified both the Little Auchinback stone and the small one in the Waukmill Glen as the Orchard Cement, largely owing to the resemblance in quality and appearance. The evidence which we have brought forward supports this conclusion.

The workings at Little Auchinback were brought to an end by a large downthrow fault running in a S.E. direction. A bore put down on the other side of the fault at this spot pierced the Arden Limestone at a depth of 10 fathoms. The fault has accordingly a throw of about 40 fathoms. Its further continuation has been noticed previously at Lyoncross, where it brings the Cowglen Limestone against the Lyoncross Coal—corresponding to a throw of 30 fathoms at this spot.

The Lyoncross Coal was worked many years ago S. of Barr-

Digitized by Google

head on both sides of the 6-fathom fault described as crossing the new cutting of the Kirkton Burn at the small plantation.

By tracing the massive pebbly grit with the underlying Cowglen Limestone and the overlying Hole Burn Coal and Limestone round the basin from Nitshill, we consider we have established the identity of the former with the limestone occurring in the reservoir, and of the latter seams with the Lyoncross Coal and Limestone. It follows as a natural consequence that the thick blaes with the two cement bands occurring higher up in the section correspond with the Orchard Blaes and Limestones, and this conclusion is borne out by the correspondence in many points of detail.

While agreeing with the previous correlation of these latter bands with those seen in the Rouken Glen, and to be described in the sequel, we cannot, in the face of such overwhelming evidence to the contrary, regard the Lyoncross seam as the Orchard, the great grit as the Giffnock Sandstone, and the reservoir limestone as the Hole Burn Limestone, as has previously been done. We consider that the Waukmill Glen section furnishes the key to the structure of the district. By comparing it with the Salterland No. 2 Bore section, we have obtained presumptive evidence of the thickness of strata intervening between the Orchard and Arden, and of the fact that no further bands of limestone occur within the interval.

We shall next compare the vertical section of the strata exposed in Waukmill Glen with those of the bores in the Arden Quarry (No. 7 of Captain Stewart) and of the bore at Thornliebank. With regard to the Arden bore not much need be said, as the section in it is practically the same as that in Salterland No. 2, and can be correlated with certainty. The coal which we take to be the Lyoncross seam, and which was poorly represented in the Salterland bore, is probably not reached. If we interpret the zone, entered "Mussels, 3 feet 6 inches," to mean a shelly limestone, as seems probable, then the limestone which we suppose to be the Lyoncross band retains its two divisions, as usual, close to each other, and surmounted by only a few feet of blaes. The Moor Rock Coal is absent, according to our interpretation, and a sandstone and thin coal have come in between the two bands of the Orchard Limestone, which, however, maintain their relative distance.

Digitized by Google

Of more importance is the correlation between the Waukmill Glen section and the Thornliebank bore (G, Plate VII.). The limestone occurring near the base of the section in the latter bore we interpret to be the Cowglen. It has been otherwise correlated with the Hole Burn Limestone, but, in the first place, it is thicker (7 feet 4 inches) than any known occurrence of the Hole Burn or Lyoncross bands. On the other hand, it is not so thick as the Cowglen has been recorded in at least one of the bores published by Captain Stewart (No. 14B). Further, the fact that the limestone is in one post, and the absence of anything to correspond with the Lyoncross Coal, both point to the correlation with the Cowglen as the more likely hypothesis. In the next place, the overlying 20 feet of dark fakes, which we are justified in regarding as blaes, is thicker than any known occurrence of the blaes above the Lyoncross Cement; but it is not thicker than the blaes above the Cowglen Limestone at Giffnock Colliery.

The great mass of sandstone which occurs in the Thornliebank bore between this limestone and the next one above it has been held to include the Giffnock Sandstone. It may equally well be the equivalent of the Barrhead Grit, which we have followed almost round the basin; this would involve a much slighter increase in the thickness of the strata than the other assumption. The coal seam (6 inches) occurring near the middle of the sandstone has been taken for the Moor Rock Coal, but it may be the same as any one of the four different seams occurring between the Cowglen and the Lyoncross positions at Giffnock Colliery. Higher up in the section a coaly blaes (5 inches) or a coaly fireclay (1 foot 4 inches), occurring a little below the succeeding limestone, may either of them represent the Lyoncross Coal. As for the overlying limestone itself, it agrees better in thickness with the Lyoncross seam than with the Lower Orchard, which in its thickest known development, apart from this bore itself, is only 2 feet 3 inches. If we suppose the two divisions of this limestone to correspond with the two bands of the Orchard, this partly disposes of the difficulty about thickness, but, on the other hand, we have to assume that 16 to 30 feet of strata are represented by no more than 1 foot 2 inches of limy fakes. If, on the other hand, we

Digitized by Google

take this band to represent only the Lower Orchard, then, apart from the difficulty about thickness, what has become of the upper band of limestone which has been found in the Waukmill Glen? In any case, the 7 feet of dark fakes or blaes above this limestone is too thin to represent the Orchard Blaes.

Just above this blaes band comes a thickness of 23 feet of sandstone, fakes, and ribs. When we bear in mind the readiness with which all sandstones thin out laterally, and pass into such assemblages of sandstone and fakes, it is natural to suppose that this zone represents the Giffnock Sandstone, restricting the term to the sandstone which underlies the Moor Rock Coal. A little higher up in the bore journal is a coaly fireclay (1 foot 2 inches), which is regarded by us as the equivalent of the Moor Rock Coal. Higher up we find more sandstone, representing the higher posts of sandstone near Giffnock, which is followed by the limestone bands accompanied by the great thickness of blaes. These we take to be the Lower and Upper Orchard seams, together with the Orchard Blaes. On comparing the journal of this bore with the Waukmill Glen section, we think it will be admitted that our interpretation presents least difficulty. In particular, if we suppose that the lowest limestone in the Thornliebank bore is the Lyoncross band, then the sandstone, &c., which separates it from the Orchard must thin out from 278 feet at Thornliebank to 100 feet only in the Waukmill Glen, and to 173 feet eastwards to Orchard. Our own hypothesis requires a thinning of from 173 to 123 feet for the same set of strata as between Orchard and Thornliebank. As it is proved that the strata in this interval thin out westwards between Orchard and the Waukmill Glen, it is natural that, at an intermediate point, like Thornliebank, they should have an intermediate thickness, and hence be thinner than at Orchard.

We have also drawn up in graphic form the journal of the Kennishead bore—No. 8 of Captain Stewart, with whose reading we agree (see I, Plate VII.). It is possible that the top band of the Orchard Cement is just "off," and that both the bands mentioned in the bore journal at about 11 fathoms are really on the horizon of the Lower Orchard. The interval between this and the Lyoncross Limestone has undergone a further

Digitized by Google

shrinkage to 72 feet, while there is nothing better in the bore journal to represent the Giffnock Sandstone than about 16 feet of sandstone plies. At the same time, the difficulties of reading the bore journal in any other way are even greater. For instance, if the limestone at 23 fathoms is the Orchard, then the Orchard Blaes is poorly represented, while the upper band of limestone has entirely disappeared.

We think that the simplest way to interpret the bore is to suppose that the Giffnock Sandstone is undergoing a thinning process in this direction, while the underlying and overlying beds, as a result, come closer together. This is often the case where thick sandstones die out between different coal seams, and it is well known that many sandstones are very inconstant, and may die out in a comparatively short distance. It may be added that we have a bore journal from a point considerably further north, at the old Lancefield Forge, not much south of the Clyde, in which the Giffnock Sandstone is poorly represented. The Barrhead Sandstone is much more persistent, and is present both in this bore and at other localities afterwards to be described.

Returning to the neighbourhood of the Waukmill Glen and proceeding eastwards, an exposure of the pebbly sandstone is seen at Hillfield Quarry by the roadside 1 mile E. of the glen. A bore put down in the field on the N.W. side of the road opposite the quarry proved 2 feet 8 inches of limestone at a depth of 2 fathoms, while 13 feet below the limestone a coal 1 foot thick and coaly blaes 2 feet 5 inches was found. From the dip in the quarry these beds must immediately overlie the grit, and, from the general section and characteristics of these strata, there can be no doubt that we are here dealing with another outcrop of the Lyoncross seams. The blaes above the limestone in this bore was only 2 feet 6 inches thick, unlike that seen in Waukmill Glen. Further east, what corresponds to the pebbly sandstone is seen about 1500 feet south of Thornliebank House, and just north of the railway, in an old quarry marked by a line of wood. Here the pebbly character is not so marked. About 200 feet north from the quarry other exposures of sandstone occur, the latter being regarded by us as occupying the position of the Giffnock Sand-

Digitized by Google

stone. Our reasons for this conclusion are as follows:—(1) The gap, taking account of the dip, is wide enough to admit both the Lyoncross Coal and Limestone; (2) we have been informed by Messrs. Baird & Stevenson that a "blue whin" was found in this position. It is extremely probable that the rock described as whin was really limestone, as this misinterpretation very often occurs.

On the supposition that the limestone occurs between these two sandstones, its outcrop must run across the northern part of the dam which has been formed on the Thornliebank Burn, and there is nothing to indicate that it does not do so. The sandstone, which forms the fall at the head of the Rouken Glen, must be the same as the one last referred to, and therefore the Giffnock. We have not been able to find any evidence of the fault which has been drawn with a dotted line in the plan accompanying Mr. Macnair's paper on "The Geology of the Rouken Glen,"* and which has been shown as crossing the Thornliebank Burn a little below the fall. On the contrary, we believe there is an uninterrupted section from the fall right up to the position of the lower band of limestone. This band occurs in the bed of the burn about 900 feet due south from Thornliebank House, and, roughly, 150 feet south from where the bands of limestone occur, to which attention has been drawn by Mr. Macnair. It is about a foot thick, and can only be seen when the burn is low. This band we interpret as the Lower Orchard Limestone. The interval from it down to the fall is almost entirely occupied by sandstone. There is a thin coal just below the limestone which we take to correspond with the coal immediately below the Orchard Cement at Orchard itself, while a little further down is a thin coal, which corresponds very well with the coal and blaes 1 foot 6 inches thick seen a little below the Orchard Limestone in the section of Waukmill Glen.

Above this limestone, representing the position of the Lower Orchard Limestone, comes a slight gap in the section, but by protraction it is easy to tell the thickness intervening between it and the lowest band of the limestone which has been described by Mr. Macnair. We estimate the interval to be about

* *Glas. Geol. Soc. Trans.*, vol. xii., p. 362.

Digitized by Google

d by
ard,
re it
tone
tion
tone
sent-

the
aigs
sent
and
uite
outh
the
tion
nite-
rom
n a
We
me-
our

the
lam
eral
ing
ed.
all
of
to
he
th

gs
s,
of
e
t

Digitized by Google

Digitized by Google

4 fathoms, the upper part of it, at any rate, being occupied by blaes. The second limestone we regard as the Upper Orchard, exactly as it was shown on Captain Stewart's plan. Above it comes a further thickness of blaes, with one thin limestone band, and then sandstone. The accompanying vertical section (H, Plate VII.) will show how well these bands of limestone correspond with the limestones which we regard as representing the Orchard positions in the Salterland No. 2 Bore (E).

Coming now to the ground a little further to the east, the supposed presence of two separate limestones at Whitecraigs was at one time regarded as a difficulty in accepting our present theory as to the number of limestones between the Cowglen and Arden (see Fig. 3). It was supposed, and as we think quite correctly, that the limestone which occurs at the roadside south of Whitecraigs House is the Hole Burn band. If, then, the limestone which was formerly exposed at Whitecraigs Station is a higher one, it must be the Orchard, and, as the Whitecraigs Station Limestone had quite a different character from either of the bands in the Rouken Glen, these must form a separate horizon presumably higher than the Orchard. We shall try to show, however, that the disposition of the limestones can be quite well explained in accordance with our present theory.

In the first place, on the assumption that the outcrop of the Lyoncross Limestone runs across the north end of the dam on the Thornliebank Burn, as mapped by us, the general strike of the strata would make it reach the railway cutting just about the place where a limestone was actually exposed. In the second place, the coal, which was worked to a small extent at a point beneath the railway bridge to the south of the dam, is not too far below the position of the limestone to be the Lyoncross Coal. Lastly, it can be proved that the limestone at Whitecraigs Station is the same as the one south of Whitecraigs House.

The sandstone which overlies the limestone at Whitecraigs Station can be seen on both sides of the cutting, and is, approximately, horizontally bedded. From the south side of the cutting it is only 200 feet to the north-east corner of the plantation, which is occupied by Whitecraigs Quarry, and at

Digitized by Google

that point another exposure of sandstone is to be seen. At first sight the sandstone here appears to dip to the north, but on further investigation this is seen to be due to false bedding, and the actual lie of the strata can be seen quite clearly to be horizontal. Thus, this exposure of sandstone must be the same as the one in the section at the station. Sandstone is again seen just within the main gate to the grounds of Whitecraigs House, and from there it can be traced step by step south to the house itself, behind which is a lovely glaciated

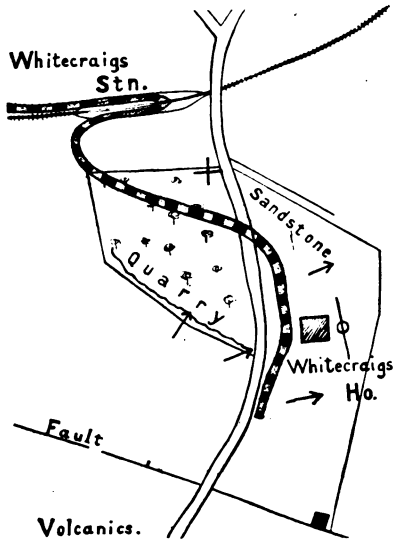


Fig. 3.

surface. From thence it stretches southwards, forming the crest of a little hill. There is nowhere room for other beds to come in, and it is quite certain that we are dealing with the same sandstone all the way from the station to the south part of the grounds of Whitecraigs House.

This is not, however, the same as the one which was mainly quarried. There is quite a considerable gap between the exposure referred to at the north-east corner of the plantation and any part of the quarried face. We were informed by the gardener at Whitecraigs House that blaes underlies the sandstone which occurs in the grounds, and he showed pieces of

Digitized by Google

limestone which had been dug up from this blaes just beneath the house. Somewhat further to the south this limestone is actually seen close to the side of the road in the place where Captain Stewart recorded it, and where it is agreed that it is the Hole Burn Limestone. Only a small exposure is now seen, and it might be regarded as an erratic but for the fact that an unsuccessful attempt was made to remove the block. From its position, from the configuration of the ground, and from the dip, which is here easterly, it is quite evident that this limestone *underlies* the sandstone on the hilltop to the east, and *overlies* the main sandstone of the Whitecraigs Quarry. Thus, its outcrop must run, as it has been sketched, across the northern part of the Whitecraigs Quarry plantation, and it must be the same limestone as was formerly seen at Whitecraigs Station. Thus, according to our view, there is no doubt that the limestone discovered there was really the Hole Burn or Lyoncross, and that the sandstone above it is the Giffnock.

Further to the east the mapping adopted by us is substantially that which was shown in the map published by Captain Stewart, and we wish again to express our very great indebtedness to him, not only for the assistance which his map afforded, but for personal help and for the communication of a large number of bore journals which he kindly made to the Survey.

We have deviated from his mapping in one respect in regarding the limestone which was found in a well at Cleuch Farm, 1 mile west of Busby, as being the Cowglen instead of the Lyoncross. The somewhat pebbly sandstone which is seen in a quarry N.W. of the farmhouse resembles more closely the sandstone above the Cowglen than the Giffnock. Also a specimen of the limestone which Captain Stewart himself showed us seemed to be more like the nearest exposure of Cowglen Limestone than the Lyoncross. Further, it must be noted that the strike of the Lyoncross Limestone on both sides of Cleuch would carry it further to the north, as is shown in our present map.

Eastwards, beside the viaduct which carries the railway across the White Cart close to Sheddens, a very fine exposure of the pebbly sandstone is seen, where it evidently overlies the

Digitized by Google

Cowglen Limestone, which is exposed lower down, in spite of the fact that the structure is complicated by one or two small faults.

Coming now once more to the north side of the basin, we regard the two bands of limestone, which have been found in the grounds of Thornliebank Print Works, somewhat to the north of the position of the bore which we have already discussed, as being a continuation of the Orchard horizon. The lower one is more probably the Orchard band itself. It is desirable to point out here that the evidence as to the number of limestones rests mainly on the mapping of the ground to the west, and on the correlation of the Waukmill Glen section with the sequence of strata in the Salterland, Arden, and Thornliebank bores. In the part of the district with which we are now dealing all we can say is that there is no evidence against our view, at any rate, so far as the stratigraphy is concerned.

Further north, as well as to the east, the mapping of Captain Stewart has been substantially followed. It is important to note that the coarse sandstone which comes between the Cowglen and Lyoncross occurs in this part of the ground as well. A large part of Pollokshaws is built upon it, as was shown when the shafts and tunnels in connection with the White Cart purification scheme were in progress. It must be interrupted by the big fault west of Pollokshaws, whose existence was first surmised by Captain Stewart, but it occurs again in a railway cutting about 2000 feet S.W. of Pollokshaws Station. It was also formerly visible just south of the White Cart, and can be seen in a line of old quarries to the south of Cowglen.

We may record here the occurrence of a limestone which was met with in the White Cart purification tunnels close to Millbrae Bridge. The section was as follows:—

	Feet.	Inches.
Sandstone,	—	—
Blaes,	5	0
Limestone,	2	0
Blaes,	2	0
Limestone,	2	0
Blaes,	8	0
Coal,	1	3
Blaes,	5	0
Sandstone over	20	0

Digitized by Google

From its occurrence in two bands with a coal seam beneath, it may reasonably be correlated with the Lyoncross Limestone.

It is no part of the present paper to describe in detail the Upper Limestone succession here advocated in the country N. of the Clyde, but it is of interest to note that a similar succession is there present. Many deep bores have been put down N.E. of Glasgow from, or from above, the Arden Limestone, right through to the Possil Coals beneath. It may be said generally that these bores show that the interval between the Arden and Cowglen Limestones is there divided into three approximately equal divisions by two limestone bands, and that the upper of these two bands, which we would refer to the Orchard, is usually characterised by a thick blaes above it, while the lower (*i.e.*, the Lyoncross) usually has a fairly thick coal (or two coals close together) 3 or 4 fathoms beneath.

These bores all show a good development of the Bishopbriggs Sandstone overlying the Cowglen, and demonstrate the remarkable persistence of this horizon. Other thin limestones sometimes appear, but are decidedly impersistent, and in the main the strata conform to the sequence described above.

Full journals of the bore and stream sections included in our table are being lodged in the Society's library, with the exception of G, which has been published (see footnote, p. 135), and I, the journal of which has already been lodged by Captain Stewart. Bores which have numbers attached to them in the map which accompanies this paper are also in Captain Stewart's list, with the exception of Salterland No. 2, which is included in our own table of vertical sections.

Digitized by Google

No. XI.—Some Dykes in the Valley of Loch Long.

By James Stark.

[Read 10th January, 1907.

On the right of the summit-level of the road leading from Garelochhead to Loch Long there is to be seen a prominent ridge running up the hillside for about a mile in a north-easterly direction. This is found to be a large dyke of red felsite from 60 to 80 feet in thickness, which has been intruded nearly in the line of the foliation of the quartz and mica schists of the district, and which is inclined with them to the south-east at an angle of about 70 degs. The dyke crosses the road close to Whistlefield Station, after which its course changes to a more westerly direction, so that it cuts the foliation of the schists at an acute angle till it disappears under the waters of Loch Long about a mile south of Portincaple Ferry.

Tracing the dyke along these 2 miles of its length, it is found to be by no means continuous, being frequently dislocated and shifted, sometimes to the right and sometimes to the left. Perhaps the largest of the visible shifts occurs about a mile to the N.E. of the railway station, where the dyke is suddenly truncated, and ends as a steep-sided ridge, standing some 40 feet over the general surface of the hill, like the end of an unfinished railway embankment. The dyke is with difficulty found again about 100 yards to the eastward in marshy ground, where it does not project over the surface of the moor, and is mostly covered with peat. Within a few yards of its truncated end the dyke is traversed at an acute angle by another large dyke of dolerite about 60 feet in thickness, which runs in a direction E. by N. from the shore at Portincaple. This dyke, which has been traced across the country for a distance of about 50 miles, does not seem to have been shifted or disturbed in any way; it must, therefore, have been intruded subsequently to the last movements of the schists, whereas the felsite dyke has obviously been involved in these movements. The direction in which the numerous shifts of the latter dyke have taken place appears

Digitized by Google

to have been a little N. of W., approximately coinciding with that of numerous faults and crushes occurring on the shores of the loch, as described by me in a paper read before this Society in October, 1905.

It has been mentioned that the dyke is inclined at an angle of about 70 degs.; therefore, these apparently horizontal displacements may be due to vertical faults. That faulting has also occurred along the line of the felsite dyke is shown by the occasional presence of a crush breccia between that dyke and the wall of its containing fissure, consisting of angular pieces of schist, vein quartz, and portions of the dyke itself, some of which are as much as 8 inches across. There is, therefore, abundant evidence of displacement and faulting of the rocks subsequent to the intrusion of the felsite dyke, but no evidence of any such movement after the intrusion of the dolerite one.

The felsite dyke probably belongs to the group of red trachytic sills and dykes, which are so numerous in the Greater Cumbrae and on the adjacent coast of Ayrshire. These were mapped a few years ago in great detail for the Geological Survey by the late Mr. W. Gunn, who says they are almost entirely confined to the Upper Old Red Sandstone, rarely entering the overlying white Calciferous Sandstones, and never invading the plateau lavas of that period. They are, therefore, probably of early Carboniferous age. The dolerite dyke of Portincaple, on the other hand, probably belongs to that group of later basic Carboniferous sheets and dykes, having an approximately east and west direction, which are abundantly developed in the Lower Limestone series of our neighbourhood. In that case, the latest movements of the marginal Highland schists in the Loch Long district appear to have taken place in early Carboniferous times, and may have some relation to the great volcanic outburst of Calciferous age, to which the bedded lavas of the Kilpatrick and Campsie Hills are due.

The felsite dyke of this paper is thus referred to by the late Dr. Bryce in his "Geology of Clydesdale"—"The appearance of the plutonic rock, now as a bed interposed among the strata, and, again, as a vein intersecting them, and the undulatory course which it pursues, point out its posterior origin and the

Digitized by Google

nature of the resisting force"; what he here calls undulations being really dislocations caused by the subsequent movement of the schists. He then goes on to say—"Near the summit of the ridge, and at a curvature of the vein, the outer or salient angle is intersected by a dyke of greenstone or basalt in such a manner that a portion of the felspathic rock is isolated between the whin dyke and the mica slate on the west side; and the continuation of the vein lies on the same side of the dyke as before the intersection." He also gives a plan of what he conceives to be the relative position of the two dykes, much in the form of the letter K, the dolerite dyke being the vertical member and the felsite dyke the two angular members of the letter, the lower one of which is produced a little beyond its junction with the vertical member. In this I think he is mistaken, at least I could not find any evidence of the upper angular member of the letter; however, my investigations on the point were cut rather short by a gamekeeper, who entertained strong objections to "theologists frae Gleska," as he called them, disturbing the game. On the east shore of Loch Long, a few hundred yards south of Portincaple, may be seen a small dyke of grey felsite, which has also been dislocated by a subsequent movement of the schists. In this case, the rocks being exposed, the line of shift can be plainly seen, filled by a crush breccia cemented in calcite. None of the dolerite dykes of the district, so far as I have been able to observe, have been similarly shifted.

Digitized by Google

No. XII.—Iron and Copper Mining in Shetland. By Robert W. Dron, A.M.Inst.C.E.

[Read 14th November, 1907.]

The mining operations referred to in this paper were carried on in the parish of Dunrossness, situated at the southern extremity of the mainland of Shetland.

The western part of this end of the island is composed of archæan schists rising in hills to a height of between 800 and 900 feet. Along the eastern coast there is a stretch of flaggy sandstones of Old Red Sandstone age. The division between these rocks is along a line running N.N.W. from Quendale Bay to Easter Quarff.

The principal metalliferous veins are situated either in the Old Red Sandstone or near the contact between the sandstones and the schists, and they run approximately parallel with the line of contact. In the western area an attempt was made early in last century to work a copper vein at Fitful, but there is no record of any extensive operations. In Robert Jamieson's "Mineralogy of Shetland," published in 1798, it is stated that at Fitful Head—"In fissures of the micaceous shistus I obtained several small portions of micaceous iron ore, which for some time amused a party of miners with hopes of immense wealth . . . below this, at Garthsness, there is a large vein of sulphuret of iron about 7 feet thick running in a stone intermediate between micaceous shistus and chlorite shistus.

"It lies exposed to this day for 20 or 30 feet, and was worked for some time, but was so unproductive that it was soon given up."

In the contact deposit, between the schists and the sandstones, attempts have been made to work iron ore at Quendale, at Levenwick, and at Hoswick. In Sir John Sinclair's "Statistical Account of Scotland" we find the following reference:—"In the years 1789-1790 Zetland was visited by some gentlemen from London, who found in the estate of Quendale a rich iron mine, and in various parts of the island the ores of copper,

Digitized by Google

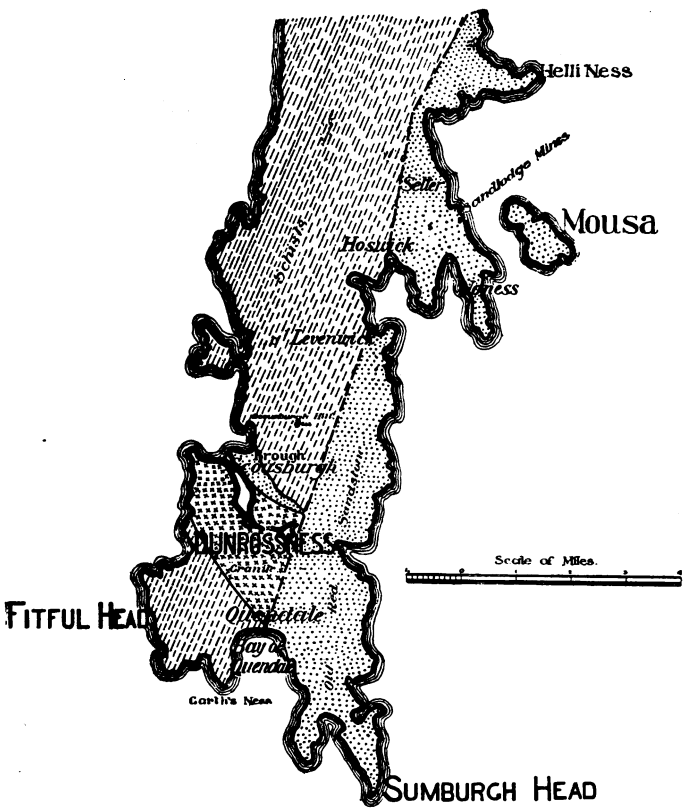
lead, and iron, samples of which were carried to London, particularly copper, in considerable quantity." In 1803 a few miners were working a copper vein at Quendale, but there appears to be no record of any further operations since that date. At Levenwick and Hoswick there are signs of some mining operations having been carried on, and local tradition says that at Levenwick a long adit level was driven in the vein, near sea-level, but this adit is not now accessible. In Dr. Heddle's "Mineralogy of Scotland" (p. 88) he refers to specular or micaceous iron ore in thin, flat crystals, "in a vein which has its north outgoing at the junction of the clay slate with the Old Red Sandstone on the west shore of Levenwick, and which courses along the east side of Scousburgh Hill. It enters the clay slate and reappears of very considerable thickness at the south-east end of Scousburgh Hill, near the Brough."

The only serious mining operations that have been carried out were at Sandlodge, on the east coast, 12 miles from Lerwick. Mr. Jamieson mentions the fact that a party of miners from Wales worked here a vein of copper pyrites about the end of the eighteenth century. He secured a sample from these workings, which assayed 18 per cent. of copper. This working does not appear to have been very extensive, and the mines were not worked with any vigour until about 1873, when they were re-opened by a Mr. John Walker. They continued in operation until 1881, and a considerable amount of capital was sunk in them. In Dr. Heddle's "Geognosy and Mineralogy of Scotland" (p. 21) he speaks pretty strongly about the mismanagement of these mines by ignorant Cornish "captains." He particularly mentions that they have apparently been quite unaware of the value of chalybite. He showed a specimen of chalybite which he found on the waste heaps to a party who had been in charge of the mine, who referred to it contemptuously as "a kind of felspar stuff." At Sandlodge there are two shafts known as the east and west shaft. The vein is about 10 feet wide, dipping towards the east at an angle of 60 degs., and with a strike N.N.W.

The vein appears to be composed principally of chalybite (or siderite). At the surface there is the usual alteration

Digitized by Google

to brown hematite iron ore. The west shaft was sunk on the incline of the vein to a depth of 180 feet. For the first hundred feet it consisted of hematite, with rich pockets of copper pyrites. Several thousand tons of this ore were shipped, and it is recorded that it contained 64 per cent. of iron. Below the 100-



Geological Map of Southern End of Shetland.

feet level the ore assumed the form of light brown spathic ore. The material shipped seems to have contained 35 per cent. of iron, with 15 per cent. of lime and magnesia, and it was also accompanied by copper pyrites. The ore above the 100-feet level was stoped out, and a vertical shaft was next sunk, so as to cut the lode at a depth of 240 feet. From the

Digitized by Google

bottom of the shaft, workings were extended downwards in the lode a further depth of 60 feet, and levels were driven northward for a distance of 220 feet, and southward for a distance of 190 feet. The width of the vein is reported to be 9 or 10 feet. The ore body exposed in these lower workings appear to have consisted of white chalybite (siderite), with chalcopyrites. Extensive crushing and washing machinery was erected for recovering the copper pyrites, but, apparently, the siderite was treated as useless gangue, and no attempt was made to recover the iron contained in it. From a return made to the proprietor, it appears that the vein yielded on an average 3 per cent. of copper. The company seems to have exhausted its capital without doing much effective work, a good deal of it having probably found its way into the pockets of promoters. The mines were shut down in 1881. When the writer visited the district in 1904 the machinery was still on the spot, but somewhat deteriorated by the weather. From the waste heaps specimens of the three classes of ore can be obtained, showing the gradation from hematite as found at the surface to white siderite as found in the lower levels of the mine. The occurrence of siderite as a white ore is rather uncommon. In appearance it is very much like calcite, and we can quite understand how it might be mistaken for that mineral. Analysis of this ore gives 3 to 4 per cent. of copper and 30 to 40 per cent. of iron, with a small percentage of manganese.

Following the line of the vein to the south, fine specimens of chalcopyrites are found in the cliffs at No Ness head. To the north a vein was discovered at Setter about half a mile from Sandlodge. From No Ness to Setter the distance is about 3 miles, and it seems reasonable to suppose that the veins found along this stretch occupy one more or less continuous fissure. Both at north and south the further extension of the vein passes under the sea.

The mine at Setter was worked in 1890-92 by a number of Shetlanders, who had obtained their mining experience in the United States. One of these gentlemen, Mr. Fred W. B. Smith, of Lerwick, has kindly given the following information for the purpose of this paper:—"Two shafts were

Digitized by Google

sunk. The first one was near the coastline, and went to a depth of 90 feet following the vein. At the surface the vein was only a few inches wide, but when the shaft was abandoned it was from 15 to 20 inches wide. This vein, so far as exposed, was lenticular in form, with a strike N.E. and S.E., and dipping to the N.W. at an angle of 60 degs. The ore was pure copper pyrites, and was shipped direct to the smelter as it came from the mine. There was difficulty about continuing the work in this shaft, owing to the proximity of the sea, and a second shaft was started about 50 yards inland on the higher ground. The second shaft was sunk to a depth of 83 feet and a crosscut started to reach the vein, but at that stage the workings were abandoned."

It may be mentioned that in Dr. Heddle's "Mineralogy of Scotland" the following minerals are mentioned as being found in the Sandlodge lodes:—Native copper with malochite chalcopyrites in a vein of chalybite tetrahedrite; crystallised white quartz—milk white with limonite, hematite, elba iron ore, wad, and siderite. Specimens of these ores are preserved in the Glasgow Museum.

Digitized by Google

No. XIII.—Lord Kelvin's Contributions to Geology.* By Professor J. W. Gregory, D.Sc., F.R.S.

[Read 9th January, 1908.]

It has been the high privilege of Glasgow University to have been the working home of the two men whose scientific genius rendered possible the present development of industry and commerce; for the distant regions of the world could never have come into such intimate relationship or helped one another by such profitable interchange of their produce had not Lord Kelvin's contributions to submarine telegraphy supplied the nerves that control the power we owe to Watt.

The incalculable service of Kelvin to civilisation in giving us the means of immediate communication with men beyond the seas, and his unrivalled contribution to the fundamental principles of science have overshadowed his influence on geology. Even in this city it is apt to be forgotten that he was for over twenty-one years (1872-1893) President of the Glasgow Geological Society, and that through its *Transactions* he issued a series of essays which have taken a secure place among the classics of geological literature.

It is unnecessary here to give any full sketch of Lord Kelvin's life, or to refer to any except his geological work, for several full appreciations have already appeared. It may, however, be advisable to record a few dates that mark the chief stages in his career. William Thomson was born on the 25th of June, 1824, at Belfast, where his father was then professor of mathematics in the Royal Academic Institute. His father was the son of a small farmer at Ballynahinch, in County Down, and had been educated in Glasgow, to which he returned as professor of mathematics in 1832. Lord Kelvin, therefore, though born in Ireland, settled in Glasgow in infancy. His early education he received from his father, and he entered the Glasgow University at the age of ten. His interest in geodesy

* Part of this paper appeared as an article in the *Glasgow Herald*, 22nd February, 1908, under the title "Lord Kelvin and the Age of the Earth."

Digitized by Google

and mathematical geology was early shown by an essay on the figure of the earth, written during the session of 1838-39, and rewarded by a University medal. He does not appear to have taken a degree at Glasgow, but after seven years' study there he went to Cambridge in 1842, the year in which he published his first original paper. While an undergraduate at Cambridge, he wrote for the *Cambridge and Dublin Mathematical Journal*. In 1845 he sat for the mathematical tripos, but, to the surprise of his friends, he was not the senior, but the second wrangler. He, however, subsequently gained the Smith's Prize. After leaving Cambridge he worked for about a year in Regnault's laboratory in Paris, and in 1846, at the early age of twenty-two, he was elected to the professorship of Natural Philosophy in Glasgow University. From that time onward his life was mainly spent in Glasgow. The teaching of his subject had previously been by lectures only, but Thomson founded a small laboratory for practical work in a disused wine cellar, which was also used as a coal cellar; and Professor Ayrton, who was one of the many distinguished electricians attracted to Glasgow in order to study for a session under Sir William Thomson, reports that they were often harassed in their experiments by the boy coming in to shovel up coals.

At Glasgow University nearly all William Thomson's work was done. He resigned his chair there in 1899, and in 1904 was elected Chancellor of the University, an office he held on his death on 17th December, 1907. He was knighted in 1866, and received his peerage in 1892; he was President of the British Association in 1871, and of the Royal Society from 1890 to 1895. He was President of this Society from 1872 to 1893.

Lord Kelvin's work was mainly connected with physical science, but he objected to the separation of natural and physical science. The title of his Chair at the University was Natural Philosophy, and though the subjects described as Natural Science have been established as independent schools, Lord Kelvin was fond of the old name, and warmly maintained his right to be regarded as a naturalist. He repudiated the title physicist as "un-English, unpleasing, and meaningless," and,

Digitized by Google

relying on Dr. Johnson's definition—"Naturalist: A person well versed in Natural Philosophy"—claimed that chemists and mathematicians are naturalists, as well as the "merely descriptive investigators of Nature."

Apart from any such question of definition, Lord Kelvin had an indubitable claim to rank as a naturalist owing to his contributions to geology. His geological contributions may be grouped into four divisions—

1. Contributions to physics which explain geological and geographical problems.
2. His calculations as to the age of the earth.
3. His disproof of the once prevalent and crude idea that the earth consists of a solid shell round a fiery or molten interior.
4. His contributions to the study of the former variations in climate.

Lord Kelvin's contributions to geology were not at one time welcomed by geologists. Huxley once repudiated his conclusions as those of a "passer-by," who was rashly meddling with other people's foundations. Lord Kelvin resented this opinion. "Is geology," he asked, "not a branch of physical science?" And he protested, "I am anxious to be regarded by geologists, not as a mere passer-by, but as one constantly interested in this grand subject, and anxious in any way, however slight, to assist them in their search for truth."* That his assistance gave a powerful and useful influence in the progress of geology will probably be admitted now by nearly every geologist.

1. *Contributions to the Physical Basis of Geology and Geography.*

The unity of natural science was illustrated by Lord Kelvin's work as well as by his beliefs. His physical researches threw light on the working of the natural agents to which the materials of the geologist are due. Geology is deeply, although indirectly, indebted to him for his explanation of various problems in meteorology; for his investigations on tides and descriptions of those of the Straits of Dover and the

* *Trans. Geol. Soc. Glasgow*, vol. iii., 1869, pp. 232-3.

Digitized by Google

Mediterranean; his studies on wave action; his contribution to our knowledge of the physical properties of ice; and his calculations as to the degree of stability of the sea level, and on the extent to which various causes may locally raise and lower it.

2. *The Age of the Earth.*

Lord Kelvin's practical achievements have abridged space; his academic contributions have shortened time. His belief that geology is a branch of physical science led to his aspiration to give geology greater exactitude by providing it with a means of determining absolute dates. Geology can only establish the relative ages of former epochs and incidents. Rough estimates of the length of geological time have been suggested from calculations of the amount of salt in the sea, or by dividing the thickness of rocks in the earth's crust by their possible rate of formation. The unknown factors are, however, so great that the results are only of use as popular illustrations of the length of the periods involved. Lord Kelvin thought that investigations of the internal heat of the earth might render it possible to replace relative by absolute dates, and determine its age in years. He claimed that this research proved the earth to be much younger than geologists and biologists had previously believed. His first statement of this conclusion took the form of a protest against that doctrine of Uniformity, the foundation of which is the special glory of Scottish geology. The title of this paper—"The Doctrine of Uniformity briefly Refuted"—was a direct challenge to the form of that theory then orthodox. Lord Kelvin's views were accordingly repudiated as a heresy based on incompetence to judge the geological evidence. His objections, however, were to the ultra-Uniformity taught by Hutton and Playfair, according to whom the geographical conditions of the earth had been constant through such immeasurable æons of time that, from geological evidence, we can "discover no mark either of the commencement or the termination of the present order."

These assumptions, excusable at the end of the eighteenth century, were a mischievous survival forty years ago. Lord Kelvin's doctrine of the dissipation of energy rendered it certain that the earth must have had a beginning under conditions

Digitized by Google

very different from those that now prevail, but of which the present order is the natural development. Lord Kelvin insisted that as both the earth and sun are using up heat and energy, the supply must come to an end and must have had a beginning. "It is as certain," he wrote, "that there is now less volcanic energy in the whole earth than there was 1000 years ago, as it is that there is less gunpowder in a 'Monitor' after she has been seen to discharge shot and shell, whether at a nearly equable rate or not, for five hours without receiving fresh supplies, than there was at the beginning of the action." He held that "it is impossible that the hypotheses assuming an equability of sun and storms for a million years can be wholly true."* Before the beginning of the evolution of life, and of the existing distribution of land and water, the earth had passed through its earlier cosmic evolution, and Lord Kelvin insisted that this early chapter in the earth's history occurred at a calculable date, and was an essential part of the subject-matter of geology.

Lord Kelvin prepared several estimates of the possible length of the time during which the earth can have been fitted for the abode of life, as well as of the maximum age of the earth. From the loss of heat from the interior, he estimated that the earth must have consolidated from a molten state not less than twenty million nor more than four hundred million years ago.† From the duration of the sun's heat he calculated a limit that might be as high as 500 million years. These limits were comfortably elastic, but later on he reduced his allowance, and claimed that the earth consolidated from a molten state at a date "more than 20 and less than 40 million years ago, and probably much nearer the 20 than 40."

This proposal to limit geological times led to a lively controversy. Kelvin's views were repudiated by Sir Andrew Ramsay, who declared that geologists and physicists stood on such different platforms that neither could understand the arguments of the other. Lord Kelvin was certainly quite capable of understanding the simple considerations of geology,

* "On the Secular Cooling of the Earth." Math. and Physic Pap., vol. iii., p. 300, par. xi.

† "The Age of the Earth as an abode fitted for Life." *Phil. Mag.*, ser. 5, vol. xlvii., 1899, p. 75.

Digitized by Google

and he courteously held that geologists could understand the physical arguments if they would only try. The most effective champion for time unlimited was Professor Huxley, who held that the physical data were so uncertain that no reliance could be placed on them. He racily described mathematics as a mill from which what you get out depends on what you have put in. If the data are uncertain, so are the conclusions; and he held that Lord Kelvin's data were so speculative that no reliance could be placed on them when they came into conflict with the direct, positive records of geology. Lord Kelvin replied that, though his data were loose, he had taken care to make his results looser. He had, however, not made them loose enough. Professor Perry has shown that, by assuming that the distribution of temperature within the earth is more uniform within the central mass than in the crust—and this assumption is more probable than Lord Kelvin's—his estimate must be multiplied 290 times, giving us 28,930 millions of years.* Any geologist who wants more is greedy; but he may perhaps get more, for the discovery of radium as a source of heat has added another factor, that gives the limits of time very generous and perhaps indefinite expansion.

Nevertheless, Lord Kelvin's protest was most useful. It had been the habit of geologists, including some of the highest authorities, to make extravagant demands on time. For instance, Darwin, from the rate of erosion of the chalk of Kent, estimated that the excavation of the great valley between the North and South Downs, "required 306,662,400 years, or, say, 300,000,000 years, and that in all probability a far longer period than 300,000,000 years has elapsed since the latter part of the secondary period." As Darwin demanded so much time, it is not surprising that others demanded more. Jukes, in his "Manual of Geology," remarks that, though Darwin's estimate might be excessive, it was just as likely that the real period was one hundred times as great, and that the erosion of the Wealden valleys may have occupied 30,000 million years. Lord Kelvin's arguments compelled geologists to reconsider the evidence for such ideas, with the result that most of us are now willing to admit that the casual estimates

* J. Perry, "On the Age of the Earth." *Nature*, vol. li., 1895, pp. 224-227, 341-342, 582-585.

Digitized by Google

of time made fifty years ago were fanciful and preposterous. Darwin, always open to conviction, omitted his 300,000,000 year estimate from the later editions of his "Origin of Species," and, according to Sir Archibald Geikie, the time allowed by Lord Kelvin is long enough for the actual records of geology. The biologists may still demand unlimited time, but their arguments do not seem convincing, for there are no data by which to express the rate of organic evolution in years. Because evolution has been slow across the short span of human records, it does not follow that it was not much quicker at epochs of great geographical and local climatic change.

Geologists have better data than biologists for estimating time; but the rate of excavation of a valley cannot be measured by the rate of progress when the work is nearly finished. The wearing away of a recently elevated land goes on with startling rapidity when compared with the rate in a mature country, which is structurally stable, having been worn down to long, smooth slopes. A geologist may admit that the powers of excavation of a mountain torrent are a thousandfold greater than those of a sluggish lowland stream without denying the great doctrine of Uniformity. Lord Kelvin was, indeed, a truer Uniformitarian than those who held the extreme views expressed in the following passage from Playfair:—"The Author of Nature has not given laws to the universe, which, like the institutions of men, carry in themselves the elements of their own destruction. He has not permitted in His works any symptoms of infancy or of old age, or any sign by which we may estimate either their future or their past duration. He may put an end, as He, no doubt, gave a beginning, to the present system, at some determinate time; but we may safely conclude that this great catastrophe will not be brought about by any of the laws now existing, and that it is not indicated by anything which we perceive." Lord Kelvin declared—"Nothing could possibly be further from the truth than that statement";* and we may add that it is quite inconsistent with the true doctrine of Uniformity. The view that the earth is progressing in an orderly development from its beginning till its end shall come gradually from the exhaustion of its stores

* *Trans. Geol. Soc. Glasgow*, vol. iii., pt. i., p. 2, 1868.

Digitized by Google

of energy, is a grander conception of geological uniformity than belief in unchanging conditions persisting between a sudden beginning, of which Nature retains no impression, and a catastrophic end, of which it gives no hint.

In this controversy, Lord Kelvin in one respect showed a deeper insight than Huxley, who, referring to possible changes in the rate of rotation of the earth, or in the heat given forth from the sun, or in the cooling of the earth, declared that geologists are Gallios "who care for none of these things." An ever-increasing school of geologists now care greatly for these questions, and revere Lord Kelvin as one of the founders of the geology of the inner earth.

3. *The Rigid Earth.*

Another important influence exercised by Kelvin on geology was his final overthrow of the once-popular belief that the earth consists of a solid shell enclosing a central fire or mass of molten rock. Lord Kelvin was not the first to preach the solidity of the earth. He was careful to give the credit of this view to Hopkins. But the reasons (based on precession) which led Hopkins to this conclusion have been recognised as invalid. Lord Kelvin originally accepted them, but after a conference with Newcomb he abandoned this part of the argument, and in his presidential address to the Mathematical Section of the British Association at Glasgow in 1876, he cancelled that part of his famous paper on "The Rigidity of the Earth." The present belief in our solid globe is due mainly to Kelvin's work on tidal retardation.

The question whether the interior of the earth is solid or fluid is, to a large extent, a matter of terms. The view that the interior of the earth is "fluid" in the technical sense of the word, is still part of geological theory. To use the language of Van Hise, below the skin of the earth, where the rocks are hard and brittle—the zone of fracture—the rocks are so hot that, though compressed, like solids, into the smallest possible space, they will change their shape and flow like fluids. That part of the earth is the "zone of fluxion"; and, as the property of flowing is the character of fluids, we may regard

Digitized by Google

the deeper layers of the earth as fluid or "fluidible," as they are certainly ready to expand into a molten state when released from pressure.

No doubt many of the earlier geologists used the term fluid as if they regarded the interior of the earth as occupied simply by molten rock. But this was probably a concession to simplicity of statement. It had been known since the time of Newton, and confirmed by the famous experiment at Schiehallion in 1774, that the earth weighs about twice as much as a ball of the same size made of the rocks of the earth's crust. As rocks, when molten, are lighter, bulk for bulk, than they are when solid, it was obvious that the interior of the earth did not consist of rocks in the same liquid state as when molten in a furnace. The facts which led geologists to the belief that the material inside the earth is fluid, like lead in a hydraulic press, are still accepted. Lord Kelvin's great service to this question was his proof that, in spite of the fluidible nature of the internal matter, the earth as a whole is as rigid as a solid globe of steel.

The Geological History of Climate.

Lord Kelvin's supreme authority on thermodynamics gave his opinion on meteorological problems especial weight, and on this subject he again showed his desire to help geological research. His study of underground temperatures enabled him to show that subterranean heat has no effect on climate, and that the warmer climates that once prevailed over various parts of the earth were not due to a greater heat supply received from the interior. This conclusion is now universally accepted, except for an occasional wild speculation, such as the recent suggestion of an Italian author,* that the warm ocean currents derive their heat from the interior of the earth. But Lord Kelvin's further inference, that the whole world once had a warmer climate, owing to the sun having been hotter, has not received further support from later geological discoveries. Despite his enthusiastic advocacy of that view—it was, he said, "the one hypothesis that is rendered almost infinitely probable by independent physical evidence and mathematical calcula-

* Ricciardi. "L'unitá delle energie cosmiche." Turin, 1907.

Digitized by Google

tion"—and in spite of its subsequent support by Sir John Murray, later discoveries as to the climates of early times have rendered it still less acceptable.

The causes of former local variations of climate were discussed by Lord Kelvin in an important address to this Society in 1877. He quoted the occurrence of trees of living species in the Arctic regions beyond the present tree limit; there is no doubt that some of them grew where they were found, such as the white pines (Abies alba) found in 74° 48′ in Bank's Land and at 75° 32′ in Wellington Sound. Lord Kelvin insists that a different distribution of land and water in the Arctic sub-Arctic regions is adequate to account for the climatic change indicated by these trees. "I see no difficulty in admitting the complete sufficiency" of this cause "to account for all that is proved of temperate climates in polar regions and of alternations of glacial and mild climates in Europe and North America and New Zealand."* "A thousand feet of depression would submerge the continents of Europe, Asia, and America for thousands of miles from their present northern coastlines, and would give, instead of the present land-locked, and therefore ice-bound Arctic sea, an open iceless ocean, with only a number of small, steep islands to obstruct the free interchange of water between the North Pole and temperate or tropical regions. That the Arctic Sea would, in such circumstances, be free from ice quite up to the North Pole may be, I think, securely inferred from what, in the present condition of the globe, we know of ice-bound and open seas in the Northern Hemisphere and of the Southern Ocean abounding in icebergs, but probably nowhere ice-bound up to the very coast of the circumpolar Antarctic continent, except in more or less land-locked bays."† And "the climate of a small island in an open iceless circumpolar sea," he said, would be "temperate and quite free from frost, except in hollows."‡ "It seems certain," he continues, "that causes," which he explains, "would suffice to prevent even so much as hoar frost on a small island at the very Pole during its whole winter six months' night, if it is surrounded by a

* *Trans. Geol. Soc. Glasgow*, vol. v., pt. ii., 1877, p. 248.
† *Ibid.*, pp. 244-245.
‡ *Ibid.*, p. 247.

Digitized by Google

deep ocean, with no land to obstruct free circulation between it and tropical seas."*

Lord Kelvin's geological work, therefore, covered a wide range, but it was all confined to the most purely theoretical questions, in which he maintained the most eager interest till the end. His attention to the economic applications of science —and he was a pioneer in the recognition of the educational value of applied science—never lessened his inspiring faith in fundamental principles or his contagious enthusiasm for the solution of theoretical problems. Reverence for his transcendant genius is combined with admiration for that completeness of character which made him a type of the ideal man of science, for he was as devoted to the quest of abstract truth and of still useless knowledge as any intellectual hermit, and he had, at the same time, the practical insight and human sympathy of a great man of affairs.

A CLASSIFIED LIST OF LORD KELVIN'S CHIEF ADDITIONS TO GEOLOGICAL LITERATURE.†

I. General Geographical and Geological Problems.

1. *Tides.*

1. 1879. "Influence of the Straits of Dover on the Tides of the British Channel and North Sea." *Nature*, vol. xix., Dec., 1878, pp. 152-154, with map. Also (without map) in "Rep. Brit. Assoc. for 1878-79," pp. 639-640.
2. 1879. [In conjunction with Captain F. J. O. Evans.] "On the Tides of the Southern Hemisphere and of the Mediterranean." "Rep. Brit. Assoc. for 1878-79," pp. 477-481.

* *Trans. Geol. Soc. Glasgow*, vol. v., pt. ii., 1877, pp. 247-248.

† References to papers dealing mathematically with Spheroidal Shells and the forms of rotating bodies, and general papers on tides are not included.

The papers, when reprinted, contain occasional amendments, some of which are important.

Digitized by Google

2. *The Physics of Ice.*

3. 1850. "The Effect of Pressure in Lowering the Freezing Point of Water Experimentally Demonstrated." *Proc. Roy. Soc. Edin.*, vol. ii., 1850, pp. 267-271. Also in *Phil. Mag.*, vol. xxxvii., 1850, pp. 123-127. And in "Math. and Physic. Pap.," vol. i., 1882, pp. 165-169.
4. 1858. "Remarks on the Interior Melting of Ice." *Proc. Roy. Soc.*, vol. ix., 1858, pp. 141-143.
5. 1858. "On the Stratification of Vesicular Ice by Pressure." *Proc. Roy. Soc.*, vol. ix., 1858, pp. 209-213.
6. 1861. "Note on Professor Faraday's Recent Experiments on 'Regelation.'" *Proc. Roy. Soc.*, vol. xi., 1861, pp. 198-204.
7. 1867. "Viscous Theory of Glaciers." In Thomson and Tait, "Treatise on Nat. Phil.," vol. i., 1867, pp. 591-592.

3. *Variations of Sea-level.*

8. 1866. Note on paper "On the Physical Cause of the Submergence and Emergence of the Land during the Glacial Epoch," by James Croll. *Phil. Mag.*, ser. 4, vol. xxxi., 1866, pp. 305-306.
9. 1867. "Sea-level and Stability of the Ocean." In Thomson and Tait, "Treatise on Nat. Phil.," vol. i., 1867, pp. 637-638 and 664-671.
10. 1888. "Polar Ice-caps and their Influence in Changing Sea-levels." *Trans. Geol. Soc. Glasgow*, vol. viii., part ii., 1888, pp. 322-340. Also in "Pop. Lect. and Add.," vol. ii., 1894, pp. 319-359.

4. *Age of Ocean Basins.*

11. 1899. "Probable Origin of Continents and Ocean Depths of the Earth." In "The Age of the Earth as an Abode fitted for Life." *Phil. Mag.*, ser. 5, vol. xlvii., 1899, pp. 81-89.

Digitized by Google

5. *Origin of Life.*

12. 1872. ["Possible Introduction of Life to the Earth by a Meteorite."] In "Presidential Address to the British Association, Edinburgh, 1871." "Rep. Brit. Assoc. for 1871-72," pp. 103-105. Also in "Pop. Lect. and Add.," vol. ii., 1894, pp. 197-205.

6. *Petrography.*

13. 1899. "Probable Origin of Granite." In "The Age of the Earth as an Abode fitted for Life." *Phil. Mag.*, ser. 5, vol. xlvii., 1899, p. 79.
14. 1899. "Probable Origin of Basaltic Rock." *Ibid.*, pp. 80-81.

7. *Waves.*

15. 1871. "The Influence of Wind on Waves in Water supposed Frictionless." [Letters to Prof. Tait, August and October, 1871.] Parts iii. and iv. of "Hydrokinetic Solutions and Observations." *Phil. Mag.*, ser. 4, vol. xlii., 1871, pp. 368-374.
16. 1871. "Waves under Motive Power of Gravity and Cohesion jointly, without Wind." Part v. of "Hydrokinetic Solutions and Observations." *Phil. Mag.*, ser. 4, vol. xlii., 1871, pp. 374-377.
17. 1872. "Ripples and Waves." [Extract from letter to W. Froude.] *Nature*, vol. v., 1872, pp. 1-3.

II. The Age of the Earth.

18. 1856. "On the Use of Observations of Terrestrial Temperature for the Investigation of Absolute Dates in Geology." "Rep. Brit. Assoc. for 1855-56," part ii., pp. 18-19. Reprinted in "Math. and Physic. Pap.," vol. ii., 1884, pp. 175-177.
19. 1860. "On the Reduction of Periodical Variations of Underground Temperature, with Applications to the Edinburgh Observations." "Rep. Brit. Assoc. for

Digitized by Google

1859-60," part ii., pp. 54-56. Reprinted as Appendix to Memoir "On the Reduction of Observations of Underground Temperature, with Applications to the Edinburgh Observations," in "Math. and Physic. Pap.," vol. iii., 1890, pp. 291-294.

20. 1861. "On the Reduction of Observations of Underground Temperature, with Application to Professor Forbes' Edinburgh Observations, and the continued Calton Hill Series." *Trans. Roy. Soc. Edin.*, vol. xxii., 1861, pp. 405-427. Reprinted in *Phil. Mag.*, ser. 4, vol. xxii., 1861, pp. 23-34, 121-135. Also in "Math. and Physic. Pap.," vol. iii., 1890, pp. 261-290.
21. 1862. "Physical Considerations regarding the Possible Age of the Sun's Heat." "Rep. Brit. Assoc. for 1861-62," part ii., pp. 27-28.
22. 1862. "On the Age of the Sun's Heat." *Macmillan's Magazine*, vol. v., March, 1862, pp. 288-393.
23. 1872. ["Age of the Sun's Heat."] In "Presidential Address to the British Association, Edinburgh, 1871." "Rep. Brit. Assoc. for 1871-72," pp. 99-100. Also in "Pop. Lect. and Add.," vol. ii., 1894, pp. 184-190.
24. 1862. "On the Secular Cooling of the Earth." *Trans. Roy. Soc. Edin.*, vol. xxiii., 1862, pp. 157-169, pl. vii. Reprinted in *Phil. Mag.*, ser. 4, vol. xxv., 1863, pp. 1-14, pl. i. Also in "Math. and Physic. Pap.," vol. iii., 1890, pp. 295-311. Also as Appendix D, in Thomson and Tait, "Treatise on Nat. Phil.," vol. i., 1867, pp. 711-727.
25. 1866. "The Doctrine of Uniformity in Geology briefly Refuted." *Proc. Roy. Soc. Edin.*, vol. v., 1866, p. 512. Appendix, "Estimate of the Present Annual Loss of Heat from the Earth." *Ibid.*, pp. 512-513. Reprinted in "Pop. Lect. and Add." vol. ii., 1894, pp. 6-9.
26. 1866. "On the Observations and Calculations Required to find the Tidal Retardation of the Earth's Rotation." *Phil. Mag.*, ser. 4, vol. xxi., 1866, pp. 533-537.* Also

*From the Rede Lecture "On the Dissipation of Energy." Cambridge, 1866.

Digitized by Google

published as Appendix B to "On the Rigidity of the Earth; Shiftings of the Earth's Instantaneous Axis of Rotation; and Irregularities of the Earth as a Time-keeper." "Math. and Physic. Pap.," vol. iii., 1890, pp. 337-341; and also as Appendix to No. 27, 1868, pp. 25-28.

27. 1868. "On Geological Time." *Trans. Geol. Soc. Glasgow*, vol. iii., part i., 1868, pp. 1-28. Reprinted in "Pop. Lect. and Add.," vol. ii., 1894, pp. 10-72.

28. 1869. "Of Geological Dynamics." *Trans. Geol. Soc. Glasgow*, vol. iii., part ii., 1869, pp. 215-240.

    Part i.—"Reply to Professor Huxley's Address to the Geological Society of London, of 19th February, 1869," pp. 215-233.

    Part ii.—"Origin and Total Amount of Plutonic Energy," pp. 233-238.

    Part iii.—"Note on the Meteoric Theory of the Sun's Heat," pp. 239-240. And also in *Proc. Phil. Soc. Glasgow*, vol. vii., 1869, pp. 111-112. Abstract of all four parts in *Geol. Mag.*, vol. vi., 1869, pp. 472-476. Reprinted in "Pop. Lect. and Add.," vol. ii., 1894, pp. 73-131.

29. 1895. "The Age of the Earth." *Nature*, vol. li., 1895, pp. 438-440.

30. 1899. "The Age of the Earth as an Abode fitted for Life." *Phil. Mag.*, ser. 5, vol. xlvii., 1899, pp. 66-90 (reprinted with additions). The Presidential Address to the Victoria Institute in 1897, with various additions.

III. The Internal Structure and Rigidity of the Earth.

31. 1864. "On the Rigidity of the Earth." *Phil. Trans.*, vol. cliii., 1864, pp. 573-582. Abstract in *Proc. Roy. Soc.*, vol. xii., 1862-63, pp. 103-104. Also in *Proc. Phil. Soc. Glasgow*, vol. v., 1864, pp. 169-170. Also in Thomson and Tait, "Treatise on Nat. Phil.," vol. i., 1867, pp. 689-704.

Digitized by Google

32. 1877. "Review of Evidence regarding the Physical Condition of the Earth; its Internal Temperature; the Fluidity or Solidity of its Interior Substance; the Rigidity, Elasticity, Plasticity of its External Figure; and the Permanence or Variability of its Period and Axis of Rotation." Presid. Add. to Sect. Math. and Physics at Brit. Assoc., Glasgow, 1876. "Rep. Brit. Assoc. for 1876-77," part ii., pp. 1-12. Printed also in *Nature*.

33. 1894. Reprinted without the personal introduction as "Review of Evidence regarding the Physical Condition of the Earth." "Pop. Lect. and Add.," vol. ii., 1894, pp. 238-272.

34. 1890. "On the Rigidity of the Earth: Shiftings of the Earth's Instantaneous Axis of Rotation; and Irregularities of the Earth as a Timekeeper." "Math. and Physic. Pap.," vol. iii., 1890, pp. 312-336. This paper is a reprint of that in the *Phil. Trans.*, vol. 153, but with the introduction to the Presidential Address to the Section of Mathematics and Physics of the British Association, 1876, substituted for the paragraphs of the original paper dealing with the argument from "Precession."

35. 1872. "The Internal Fluidity of the Earth." [Letter to G. Poulett Scrope replying to Delaunay's objections to the astronomical evidence for the earth's rigidity.] *Nature*, vol. v., 1872, pp. 256-259.

36. 1879. "The Internal Condition of the Earth: as to Temperature, Fluidity, and Rigidity." *Trans. Geol. Soc. Glasgow*, vol. vi., part i., 1879, pp. 38-49. Reprinted in "Pop. Lect. and Add.," vol. ii., 1894, pp. 299-318.

37. 1877. "On the Precessional Motion of a Liquid." "Rep. Brit. Assoc. for 1876-77," part ii., pp. 33-35. Also in *Nature*, vol. xv., 1877, pp. 297-298.

38. 1882. "On the Thermodynamic Acceleration of the Earth's Rotation." *Proc. Roy. Soc. Edin.*, vol. xi., 1882, pp. 396-405. Also as Appendix C to "On the Rigidity of the Earth," "Shiftings of the Earth's Instantaneous Axis

Digitized by Google

of Rotation," and "Irregularities of the Earth as a Timekeeper." "Math. and Physic. Pap.," vol. iii., 1890, pp. 341-350.

39. 1892. "Notes on Variation of Latitude in Reference to the Rigidity of the Earth." In "Presid. Add. Roy. Soc., 1891," *Proc. Roy. Soc.*, vol. l., 1892, pp. 226-227. Also in "Pop. Lect. and Add.," vol. ii., 1894, pp. 502-505.

40. 1893. *Ibid.*, in "Presid. Add. Roy. Soc., 1892," *Proc. Roy. Soc.*, vol., lii., 1893, pp. 308-310. Also in "Pop. Lect. and Address.," vol. ii., 1894, pp. 523-527.

41. 1908. Reference may also be made to Lord Kelvin's posthumous paper, "The Problem of a Spherical Gaseous Nebula." *Proc. Roy. Soc. Edin.*, vol. xxviii., pp. 259-302. (Completed by Mr. George Green.)

IV. Climate.

42. 1864. "On the Elevation of the Earth's Surface Temperature Produced by Underground Heat." *Proc. Roy. Soc. Edin.*, vol. v., 1864, pp. 200-201.

43. 1864. "On the Protection of Vegetation from Destructive Cold every Night." *Proc. Roy. Soc. Edin.*, vol. v., 1864, pp. 203-204. Reprinted, with title, "Protection of Vegetation from Cold." "Pop. Lect. and Add.," vol. ii., 1894, pp. 1-5.

44. 1877. "Geological Climate." *Trans. Geol. Soc. Glasgow*, vol. v., part ii., 1877, pp. 238-250. Also in "Pop. Lect. and Add.," vol. ii., 1894, pp. 273-298 (without map).

Digitized by Google

No. XIV.—The Passage of a Dolerite into a Hornblende Schist.

By Frederick Mort, M.A., B.Sc., F.G.S., *Hon. Secretary.*

[Read 9th January, 1908.]

Dolerite is one of the commonest rocks in the district round Glasgow, and in the Highland metamorphic area hornblende schist is by no means rare. It is probable that in many cases the hornblende schist has arisen from the metamorphism of a basic igneous rock, yet recorded instances showing the complete change from one type to the other are extremely few. That hornblende schists have originated in this way was first proved by Dr. J. J. H. Teall twenty years ago, when he published his classic paper on the Scourie dyke.

The rocks described in this paper occur as outcrops on Littleton Hill, near Colmonell, in the midst of one of the serpentine areas between Ballantrae and Girvan. The closeness of the outcrops to each other in the field, and the fact that the one extreme type is seen to merge gradually into the other, show conclusively that the different rocks described are not disconnected outcrops, but modifications of the same original rock type. Five rock types may be taken as representing the complete passage from the dolerite to the schist, and a short description of each is given below.

1. *Olivine Dolerite.*—The rock consists chiefly of plagioclase felspar, augite, olivine, and magnetite. The felspar is colourless, lath-shaped, and not much decomposed. From an estimate of its refractive index by Beck's method, and the angles of symmetrical extinction by the method of Lèvy and Lacroix, it is perhaps an acid labradorite.

The augite is pale brown in colour, and its cleavage and crystalline form are not well marked. The olivine is not abundant, and occurs in colourless, rounded grains, sometimes altered to yellow or green serpentine and black grains of magnetite. The felspar is enclosed by plates of augite, that is, it possesses a well-marked ophitic structure which is char-

Digitized by Google

acteristic of a typical dolerite. The rock in most cases is quite fresh, and shows only slight traces of any alteration.

2. *Altered Dolerite.*—Under the microscope a slide of the foregoing rock shows in a very few places the beginning of the alteration. The augite is beginning to change into a pale brown, scaly hornblende, and in these places a granular structure can be observed in the augite, at a first glance like an incipient crushing.

3. *First Passage Type.*—The rock can no longer be called a dolerite, as both minerals and structure have undergone a change. A good deal of the felspar has been altered. The lath-shaped crystals are replaced by rounded grains, and twin striation has largely disappeared. The augite has in great part been changed to brown hornblende, and the ophitic structure has been largely obliterated. The rock, however, still preserves quite sufficient of its original characters as to leave no doubt as to its origin. It may be called a granulitic hornblende gabbro.

4. *Second Passage Type.*—Hardly any trace of the original appearance of the rock is preserved. It consists chiefly of a granular mixture of hornblende and felspar. On careful examination a very little augite can be seen unchanged. The large lath-shaped crystals of felspar have nearly all been changed to a granular mosaic of small, clear, rounded crystals. The lamellar twinning has almost completely disappeared. A few olivine crystals remain in a fairly fresh condition. The rock may be called a granulitic hornblende-olivine gabbro.

Both of the passage types described are beginning to show a slight, parallel arrangement of the minerals.

5. *Hornblende Schist.*—Not a trace of augite now remains, but in its place is found a green hornblende of the colour and form found in most hornblende schists. It is distinctly pleochroic, changing from a dark brownish green to a light green. The crystals are larger and better formed, and show a distinct cleavage. The felspar has completely re-crystallised in rounded granules, lath-shaped outlines and twin striation having disappeared. A reddish brown biotite mica is also present. A schistose structure has been super-induced, and in every respect the rock is a typical hornblende schist.

Digitized by Google

Dr. Teall attributed the change in the Scourie rock to dynamic metamorphism, or, in his own words, to "high pressure at ordinary temperatures." This explanation has been generally invoked to explain the re-crystallisation of most of the Highland schists. At first sight the breaking down of the rocks described in this paper into a granulitic mosaic with a schistose structure might be taken as evidence of powerful crushing, but the appearances are misleading.

It is difficult on *a priori* grounds to understand how crushing alone can effect re-crystallisation, and there is evidence showing fairly distinctly that in this instance the final hornblende schist is not the result of dynamo-metamorphism. In the altered parts of the rock first described, the augite has broken up into granules, but in every case the felspar crystals next these augites show no trace of crushing, yet felspar is more brittle than augite. Again, in the description of the fourth type, it was stated that the rock was almost wholly a granulitic mosaic of felspar and hornblende. Yet in this matrix fairly large olivine crystals occur showing not a trace of crushing, in spite of the fact that olivine is one of the most brittle of rock-forming minerals. No trace either of strain shadows can be seen in any of the minerals under polarised light. The passage types in hand specimen recall very markedly the hornfels types of certain contact metamorphic areas.

It should be added that a number of rocks from this district resembling the intermediate and final types here mentioned have been described by Dr. Teall in the Silurian Memoir of Drs. Peach and Horne, but they did not meet with the original dolerite described above, from which the Littleton Hill rocks have been derived.

To find a complete series of rocks passing gradually from a dolerite to a hornblende schist is interesting, but it seems to me that the most important point in connection with these specimens is the evidence they give that dynamo-metamorphism, in this particular instance at any rate, is insufficient to explain the phenomena.

It is possible that the rocks may represent the Ordovician lavas altered by the intrusion of the serpentine, although the dolerite here described does not seem to resemble very much the so-called "diabase porphyrites" described by Dr. Teall in his petrological notes contributed to the Silurian Memoir.

Digitized by Google

Description of the Photomicrographs.

Figure 1—*Olivine Dolerite near the Summit of Littleton Hill, Colmonell.*—The white areas in the photograph are plagioclase felspar. Most of the darker patches are crystals of augite. Towards the right, cleavage lines can be made out in some augite crystals. In several places it can be seen that the augite is partially surrounded by felspar, that is, the rock presents an ophitic structure. The blackest spots are small crystals of magnetite. The augite is fairly fresh, but about the centre of the figure it is beginning to show the first signs of alteration into a scaly brown hornblende.

Figure 2—*Passage Type (Hornblende Gabbro) ½ mile S.W. of the Summit of Littleton Hill, Colmonell.*—The photograph shows that the rock, both in structure and in the minerals present, has been much altered. The darker areas consist of greenish brown hornblende, and the white patches indicate felspar. The latter mineral has largely re-crystallised. There is still some augite present, shown at the right-hand, top corner of the figure. It can be seen that a parallel arrangement of the minerals is beginning to take place.

Figure 3—*Passage Type (Olivine-hornblende Gabbro) S.W. Slope of Littleton Hill, Colmonell.*—The centre of the figure is occupied by a large crystal of olivine, surrounded by a ring of serpentine and black magnetite. The rest of the photograph shows a granulitic mixture of brown hornblende and clear felspar. Although the broken-up, granulitic structure of the rock suggests at first sight that it has been crushed by pressure or movement, this cannot have been the case, for the olivine crystal shows no sign of crushing, either in ordinary light or under crossed nicols.

Figure 4—*Hornblende-biotite Schist, ½ mile S.E. of Summit of Littleton Hill, Colmonell.*—The rock is a typical hornblende schist. Most of the dark streaks consist of green hornblende. Reddish-brown biotite can be distinguished by its slightly darker and smoother appearance. Two crystals of biotite may be seen at the right-hand end of the dark streak stretching right across the figure towards the top. The white areas consist of felspar, quite clear and re-crystallised. The schistose structure of the rock is brought out quite plainly by the photograph.

Digitized by Google

Fig. 1.—Mag. 16 diams.

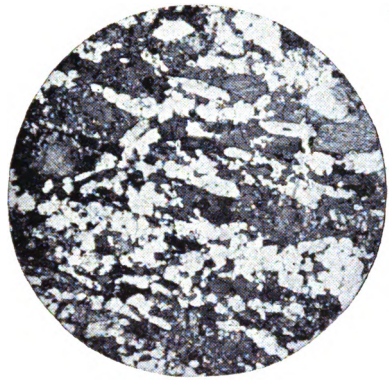


Fig. 2.—Mag. 16 diams.

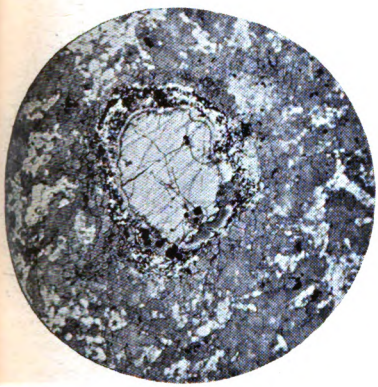


Fig. 3.—Mag. 16 diams.

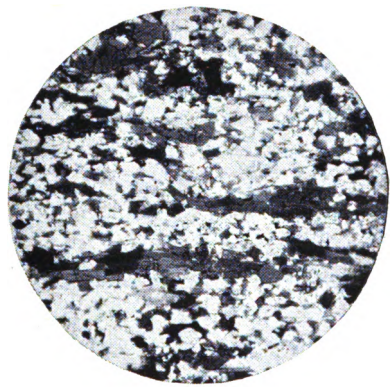


Fig. 4.—Mag. 16 diams.

Digitized by Google

Digitized by Google

No. XV.—Notes on the Geology of South-east Arran.

By James Stark.

[Read 9th January, 1908.]

The rocks exposed along the shores of S.E. Arran belong to the upper member of the lower division of the Trias. The red sandstones of Clauchland shore and Holy Isle are seen to pass upwards into a series of yellow and white sandstones, the latter being in places highly calciferous, and, consequently, weathering into very irregular forms through the solution of the contained carbonate of lime. On the inland hill slopes these rocks are seen to pass conformably upwards into a great series of red, mottled, and olive green, marly sandstones and shales, which are classed as Upper Trias, and are probably the equivalents of the Keuper series. The whole of these rocks dip westward at low angles, and the Upper Trias alone, unless repeated by faults, must attain a thickness of about 1000 feet. With the possible exception of a few occasional markings like worm tracks, the whole series appears to be destitute of any evidence of organic existence.

An outstanding feature of the geology of this district is the numerous basic sills intruded among the sandstones, which do not seem to have reached the surface at the time of intrusion, but have been laid bare by subsequent denudation.

One of the best exposures of these sills occurs at the south end of the Holy Island and along the shore westward of King's Cross Point. Tracing the sill from the east, it rises from under the waters of the Firth, and passes upwards across the horizontally bedded sandstones, till at the south end of the Holy Island the base of the sill is about 150 feet over sea-level. It then as rapidly descends till, on the western shore of the island, it again dips under the waters of the strait which forms the southern entrance to Lamlash Bay. The lighthouses on opposite sides of the island are both built on the sill, which must here considerably exceed 100 feet in thickness, its upper surface being nowhere seen.

Digitized by Google

On the other side of the strait the sill reappears at King's Cross Point, the base not being laid bare at low water, while it is distinctly in evidence on both the 50-feet and 100-feet beaches, which are here prominent features. Traced further west, it is seen to split up into several branches within 200 yards of the point. The lowest of these, which is about 10 feet thick, occupies the foreshore for a considerable distance from below low-water mark. Being columnar in structure, it forms a fine Giant's Causeway, but, owing to the disintegration of a strip of sedimentary rock entangled within it, the upper part has been undermined by the surf, and a large area of the beach is encumbered by its ruined columns. Further west the foreshore is occupied by an extensive tract of white calciferous sandstone, hardened in places to quartzite by a branch of the sill, which at low water can be seen to underlie it. Meantime, the great bulk of the sill has invaded higher and higher strata, until it disappears altogether from the old coast line, leaving the shore encumbered with rounded blocks, as evidence of its presence further inland. Numerous ramifications of the sill appear at various levels in both branches of the burn which crosses the sands to the north of Whiting Bay, and one branch forms a long, prominent platform on the hill slopes behind Auchencairn, at an elevation of about 350 feet over sea-level.

Where comparatively thin, the material of the sill may be termed a compact basalt. This is also the texture of the base of the sill before it subdivides. Further up, the sill becomes more acid in its composition, and is intersected by numerous strings and veins of basic material, which appear to be segregations during the process of cooling. Still further up, the central parts of the sill become coarsely crystalline, and resemble a gabbro. Having cooled down after the external surfaces of the sill had solidified, contraction has, in places, resulted in the formation of cavities, which have been subsequently infilled with zeolitic minerals.

A similar sill, or series of sills, occurs at the south end of Arran. At Dippen Head the whole height of the sea cliff presents a fine section of a great sill, except at one point, where the sandstones may be seen to extend about half-way

Digitized by Google

up the cliff, the sill bending over them like a great arch. This sill must exceed 200 feet in thickness, and, like that at King's Cross, it also invades higher and higher platforms of the sandstones, and subdivides and thins out as it is traced towards the west. From below sea-level at Dippen it attains an elevation of 400 to 500 feet in Glenashdale, and the terraced outlines of the hills of this district, which, from a distance, greatly resemble a series of bedded lavas, appear to be due to the numerous ramifications of this sill.

The sources from which these sills have been intruded would therefore appear to have been situated to the east or south-east of the present coast line, and to be now concealed by the waters of the Firth. Enormous denudation has taken place, and it is probable that, but for the protection afforded by the sills, the whole of the soft Triassic sandstones of this part of Arran would long since have disappeared.

Subsequently to the consolidation of the sills, the plutonic forces have broken out afresh, and have rent both them and the sedimentary rocks among which they had been injected into numerous fissures, between whose gaping walls molten rock has again arisen from the same deep-seated reservoir, and consolidated into the basaltic dykes which are now seen to traverse sandstones and sills alike.

A still later, and probably the concluding phase of the great early Tertiary period of volcanic activity, appears to have resulted in the intrusion of numerous acid sheets and bosses in the southern part of Arran. It is noteworthy that none of the basic sheets or dykes are seen to invade the felsite bosses of the Holy Isle, Dundhu, or Drumadoon, although basic dykes are not uncommon in the granite of the northern part of the island. Not only is this the case, but at the south end of the Holy Island, where the King's Cross sill is exposed in the coast cliff, resting on the red sandstones, the felsite is seen coming up in a broad band (200 to 250 feet) from below sea-level, and traversing both sandstones and sill; it appears to be the pipe, or one of the pipes, through which the intrusion of the felsite was effected. These felsite sheets and bosses would, therefore, appear to be the very latest results of plutonic action in this part of Scotland.

Digitized by Google

Both basic and acid sills have greatly altered the sedimentary strata into which they have been injected. This is shown in a marked degree in the case of the felsite of the Holy Island, and is probably due to the bulk of the intrusion and consequent length of time during which it was slowly cooling down. The red sandstones are converted into white quartzites for a very considerable distance below the surface of contact, and in places are rendered highly columnar. The felsite itself is, for the most part, of a platy structure, though in places showing rows of vertical or slightly inclined columns. An extensive sheet of similar felsite, which occurs near the summit of the hills to the west of King's Cross, displays, where sections are cut by the hill streams, a very perfect columnar structure.

The surface of the sill at King's Cross Point and on the shores of the Holy Isle opposite, up to the 25-feet beach, still bears the marks of intense glaciation. The channel between is quite in the path of the ice as it streamed down from the hills on the north, and the ice must have been tightly jammed between the Holy Isle and King's Cross Point. To the consequent severe erosion of the sill at this point, the formation of the southern entrance to Lamlash Bay is probably due. Previous to the glacial period the northern entrance was probably part of the valley of the streams which now debouch into Lamlash Bay.

The summit of the hills to the west of King's Cross forms an irregular plateau at an elevation of 1100 to 1200 feet, which has been covered with a deposit of peat to a thickness of from 3 to 5 feet. In many places this is now being rapidly denuded away, leaving exposed a thin soil of clay and coarse sand, with many boulders of granite from the Goat Fell Hills, and a few others which appear to be foreign to the island. Where the peat still remains it is frequently honeycombed with deep moss-hags. The present rapid denudation of the peat from extensive areas where it formerly grew must be due to some change of climatic conditions, and may point to a recent increase in the rainfall of the district.

Digitized by Google

No. XVI.—Petrographical Notes on a Dyke crowded with Rock Fragments near Barrhead.

By G. W. Tyrrell, A.R.C.Sc., Assistant in Geology, Glasgow University.

[Read 13th February, 1908.]

I. Introduction.

The dyke which forms the subject of this paper is exposed in the new cutting of the Caledonian Railway to the S. of Barrhead. It was discovered by Mr. R. G. Carruthers, of the Geological Survey, during the revision of the geology of this area for the forthcoming map of the Glasgow district. It was seen by the members of this Society in the course of an excursion to the new cutting, led by Mr. Carruthers. A description of it occurs in another paper contained in the present volume of the *Transactions*.*

The following notes present an account of the petrographical characters of this dyke, and of the metamorphism superinduced in the varied and numerous rock fragments or xenoliths embedded in it.

The new cutting extends from the junction of the Neilston and Lochlibo roads, on the S. of Barrhead, to near the Balgray Reservoir. Its direction is therefore W.N.W. to E.S.E. The deep gorge of the Aurs Burn, spanned by a lofty bridge, divides the cutting into two nearly equal parts. For the most part the rocks exposed are near the horizon of the Cowglen Limestone, which is twice exposed in the cutting.

The dyke appears in a shallow part of the cutting, a few hundred yards east of the Aurs Burn. It rises through the loose and incoherent white sandstone, called the Barrhead Grit by the officers of the Geological Survey. According to them, the Barrhead Grit forms a constant and easily recognisable horizon throughout this district. Within two feet of the dyke, this rock, which ordinarily crumbles into a yellowish sand, has

* R. G. Carruthers and E. M. Anderson, "Stratigraphy of the Arden Basin."

Digitized by Google

been indurated, and converted into a hard, greenish quartzite. The hardened rock stands out prominently on the margins of the dyke.

The dyke itself, however, shows features of unusual interest. When examined closely, it is seen to be crowded with an enormous number of rock fragments, mainly sandstone, shale, and limestone, ranging in size from boulders six inches in diameter to small chips and isolated crystals. These may be seen on any clean surface, the most prominent inclusions being rounded fragments of black shale, which stand out clearly in contrast with the dull green of the dyke rock. No hand-specimen can be taken which does not show a large number of inclusions. It is not too much to say that the aggregate bulk of inclusions exceeds that of the igneous rock in which they are embedded.

All the xenoliths show traces of considerable alteration. The sandstones have been indurated into a greenish quartzite, the shales hardened and hornfelsed, and the limestones rendered crystalline with the production of new minerals.

II. The Dyke Rock.

In hand-specimens the rock of the dyke itself is very soft, and of a dull green colour. The application of acid shows it to be full of carbonates. The rock has the appearance of having suffered extreme weathering.

This is confirmed by the study of a thin section. The groundmass of the rock is composed of an indeterminate brown substance, which, under a high-power objective, is resolved into a fine brown dust mixed with calcite. Pseudomorphs in calcite after original porphyritic constituents are numerous. The shapes of the phenocrysts have been unusually well preserved. Characteristic prismatic sections indicate the former presence of felspar, whilst original olivine is indicated by stout hexagonal forms. Some of the pseudomorphs, also, have shapes which suggest original porphyritic augite. In spite of the extreme alteration, therefore, the rock may be identified as a porphyritic olivine basalt, resembling the well-known rock of the Lion's Haunch of Arthur's Seat.

Numerous xenoliths of various kinds of rock, and many scattered xenocrysts of quartz and various species of felspar,

Digitized by Google

are enclosed in this rock. The broken crystals of quartz and felspar have been corroded and rounded by the action of the molten magma. The felspars have been partially or wholly cleared of their decomposition products, and the quartz is usually invested by a zone of fibrous green chlorite besprinkled with magnetite dust. This material undoubtedly represents a weathered zone of interaction between the quartz and the basalt magma.

Such interactions have often been described in petrographical literature. Mr. Harker has recently described several interesting cases among the basic dykes of Skye, in his Memoir on the Tertiary Igneous Rocks of that island. He instances a dyke, 27 feet in width, which at first glance presents the appearance of a quartz conglomerate, because of the white quartz and quartzite pebbles with which it is crowded. These have been derived from the adjacent Triassic conglomerate and the subjacent Torridonian.

The zone of interaction of the quartz grains with the basic magma consists in this case of fine needles of felspar with abundant augite granules.* It is reasonable to suppose that a similar reaction has taken place between the quartz and the magma in the present instance; but the products thereof have been destroyed in the general weathering, and are now represented by an encircling zone of alteration products.

The larger grains of quartz have been broken up into small pieces, which have been separated by the flow of the magma. Strain shadows, caused by the heat to which the mineral has been subjected, are frequently seen.

Many vacuoles occur in this dyke. These are generally filled with concentric shells of calcite, "green earth," &c., and other indefinite decomposition products.

The extreme alteration of this rock may perhaps be accounted for by its heterogeneity. The numerous xenoliths have broken up the continuity of the mass, and have afforded innumerable channels along their boundaries for the percolation of weathering agents. In thin section the enclosures are often seen to be outlined with calcite, "green earth," and other decomposition products.

* Harker. "Tert. Ign. Rocks of Skye" (1904), 352-353.

Digitized by Google

III. The Xenoliths and their Metamorphism.

The sandstone xenoliths enclosed in the dyke have been converted into a hard greenish quartzite. From the gutter near the exposure was obtained a cuboidal block of indurated sandstone, of about 4-inch edge, with a thin layer of basalt, from ½ inch to 1½ inches in thickness, still adhering to one face. The greenish basalt is full of fragments of black shale, one of which is 2 inches in diameter. This block may have been derived from the margin, or from a larger block of sandstone enclosed in the dyke.

A thin section of this rock from the junction with the basalt shows a clastic aggregation of rounded and sub-angular grains of quartz, with a few fragments of orthoclase, microcline, and flakes of muscovite. There is also a considerable amount of chalcedonic silica. Numerous intercrossing streams of minute inclusions preserve their continuity across many adjacent quartz grains. The cementing material is the basalt magma itself. The same material as that which occurs in the groundmass of the dyke rock occurs in the interstices, binding the grains together. There is also abundant calcite and serpentinous substances. The manner in which the igneous rock has penetrated the minutest interstices of the sandstone demonstrates the extreme liquidity of the molten material at the time of intrusion.

Microscopic examination of the Barrhead Grit shows it to contain the same constituents, *i.e.*, quartz, microcline, orthoclase, and muscovite, as the quartzite. Thorough permeation by the basalt magma has converted the loose, crumbling, porous grit into a hard and durable rock.

Such intractable material as this highly siliceous grit has naturally suffered little thermo-metamorphism. The utmost mineralogical alteration to be seen is a little clearing of the detrital felspar on the boundaries of the quartzite xenoliths. The long, intercrossing streams of minute inclusions penetrating the quartz mosaic may also be considered an effect of thermo-metamorphism.

The limestone xenoliths have been highly metamorphosed, and now present the appearance of a crystalline limestone.

Digitized by Google

They are usually green in colour, mottled sparingly with red or pink. They contain outstanding crystals of a dark green cleavable mineral, and many black, lustrous, metallic specks.

In thin section the rock is seen to consist essentially of an even-grained mosaic of granular calcite, interspersed with shapeless areas of a dirty green substance, which, with a high-power objective, are resolved into masses of interlacing green fibres. This mineral also occurs in large, homogeneous, prismatic crystals. It is highly pleochroic from yellowish to bluish green, has a strong prismatic cleavage, straight extinction, and low polarization colours. Its characters correspond closely with those of the chloritoid group. There are also irregular, colour-

Fig. 1.

less areas which break up into a very low-polarizing aggregate between crossed nicols. These are probably brucite.

The lustrous metallic constituent above mentioned appears in thin section as an irregularly shaped, highly refracting, isotropic mineral, a deep reddish brown in colour, which is either picotite or chromite.

This rock, therefore, is an ophicalcite, and is closely related to the calcite-brucite rocks from the Tyrol, known as predazzite and pencatite, and to those described by Dr. Teall from the Assynt district of Sutherlandshire.*

*Teall. Summary Progr. Geol. Sur., 1900, pp. 153-154. Geol. Structure of N.W. Highlands (Mem. Geol. Sur., 1907), pp. 453-462.

Digitized by Google

The original rock, of which this is the metamorphic representative, was undoubtedly an impure dolomitic limestone, rich in magnesia, iron, and alumina. The cement limestones of the Carboniferous Limestone series of this district answer perfectly to this description. Since the Cowglen Limestone lies not very far below at the point where the dyke rises to the surface, it is very probable that the ophicalcite xenoliths represent fragments of this seam.

There now remains to describe one or two further varieties of xenolith. The black shale enclosed in the dyke has been imperfectly recrystallised or hornfelsed, with the production of a minute crypto-crystalline aggregate. A thin section shows a yellowish crypto-crystalline groundmass, thickly and uniformly sprinkled with minute darker spots. There are also irregular segregations of opaque, black, graphitic material, which represents the carbon of the original rock. In polarized light there appear rectangular areas differentiated from the matrix by a lighter colour. These are, so to speak, embryos, which would have developed into a mineral peculiar to the contact metamorphism of clay rocks, most probably andalusite or chiastolite, had the metamorphism been more severe.

A thin section of another xenolith presents the appearance of a cataclastic mica schist in miniature. It shows minute angular grains of quartz embedded in an indeterminate greyish groundmass, with a dirty-brown wispy, micaceous mineral, probably imperfectly developed biotite, in folia, which wind round and enclose the quartz grains. Further metamorphism would have resulted in the production of a normal biotite schist. The rock was originally a sandy shale, and the foliation is simply an accentuation of the already existing parallel arrangement of the constituents due to bedding.

IV. Origin of the Xenoliths.

The number and bulk of the xenoliths seem to preclude the possibility of their having simply been torn off the sides of the fissure by the ascending magma. More probability attaches to the view that the rock fragments were anterior to the ascent of the magma, and were formed by the attrition of the sides of the fissure. There is no evidence of a vertical dislocation

Digitized by Google

in the neighbourhood of the dyke. The adjacent strata are horizontal, and apparently undisturbed. The movement which produced the fragments was therefore probably lateral, and need not have been of great extent. It is quite conceivable that a lateral movement, perhaps to and fro, with a very small amplitude, would be capable of producing a large number of fragments. Nevertheless, the phenomena of the dyke cannot be ascribed to the permeation of a zone of shattered and brecciated rock; for, if so, at any given point we should expect to find an overwhelming predominance of one kind of xenolith, at this particular point, of sandstone. In point of fact, however, a more or less extensive intermingling has taken place. Although there is a majority of sandstone xenoliths, there is still a very considerable proportion of shale and limestone. We are therefore compelled to assume a widening of the fissure sufficient to allow of an extensive intermingling of different kinds of xenolith. It is more than probable that this widening was concomitant with the ascent of the magma.

Three distinct processes are to be distinguished in the phenomena of this dyke—(1) The production of rock fragments by the attrition of the sides of a fissure in a small lateral movement; (2) subsequent widening of the fissure; (3) ascent of a basaltic magma of such liquidity that it was able to effect a more or less complete intermingling of rock fragments from various depths. The widening of the fissure and the ascent of the magma probably occurred at the same time.

EXPLANATION OF FIGURE.

A. Xenolith of Ophicalcite, x 25. Ord. light. Groundmass consists of a calcite mosaic. Towards top of figure are rectangular sections of a mineral allied to chloritoid, and irregular, highly-refracting granules of picotite. At bottom are one or two clear areas of brucite.

B. Xenolith of Quartzite, x 25. Ord. light. The rock consists of quartz grains cemented together with decomposed basalt substance, consisting of serpentinous material with separated magnetite, calcite, and an indeterminate brown dust.

Digitized by Google

No. XVII.—The Occurrence of Ultra-Basic Rocks in the Igneous Intrusions of the Lugar and Cumnock District.

By Robert Boyle, B.Sc., A.G.T.C.

[Read 12th March, 1908.]

I. Introduction.

The igneous intrusions of the Lugar and Cumnock district in Ayrshire are remarkable for a series of dykes, sills, and irregular segregated masses of the ultra-basic rocks, peridotite and picrite, which they contain. In this paper the term "peridotite" is restricted to a holocrystalline rock of ultra-basic composition, in which olivine is the most prominent constituent and felspar typically absent. Picrite is an exactly similar rock, but with subordinate plagioclase felspar. Peridotites usually contain olivine and magnetite, titanoferrite or chromite, with hornblende, augite, one of the pyroxenes or biotite. The silica percentage is typically less than 45 per cent., and the specific gravity from 3 to 3·3. These ultra-basic rocks resemble strongly in composition, though not in texture, the stony meteorites from extramundane space.

II. Previous Records.

Rocks of this series are comparatively rare. The first British rock which was definitely recognised and described as picrite was the augite picrite of Inchcolm, in the Firth of Forth. It was collected by Mr. Ady, and described by Dr. A. Geikie in 1880 (*Trans.* Roy. Soc. Edin., vol. xxix., p. 506). It forms a very prominent wall-like cliff of a rich brown colour, and is very destitute of vegetation on the east side of the landing-place by the Abbey. Augite picrites also occur in Shropshire and at Highweek, Devonshire; hornblende picrite occurs at Greystones, in Wicklow; and a rock which varies from hornblende picrite to hornblende peridotite is found at Penarfynnydd, in S.W. Caernarvonshire and in Central Anglesey. There are rocks rich in olivine in the western

Digitized by Google

islands of Scotland, in the gneiss area of Sutherland, where we find enstatite picrite, in North Wales and in Cornwall. Rocks have been found at Breaker Hill and Balhamie Hill, in Ayrshire, where they vary from a hornblende picrite to a hornblende peridotite. These districts are all mentioned by Harker ("Petrology for Students"). A picrite has recently been described as occurring at Ardrossan, in Ayrshire. Limburgite, the glassy equivalent of peridotite, has no exact representative in the district about to be treated, but it is found at Whitelaw Hill, in Haddington. Most of the serpentines, as, for example, those at Lendalfoot, Ayrshire, are decomposed peridotites. Lastly, it should be mentioned that peridotite and picrite were recorded a few years ago, for the Lugar district, by Mr. George Knox in a paper before Glenfield Ramblers, Kilmarnock.

III. District.

The district to be described lies mainly a few miles east of Old Cumnock, in Ayrshire, and embraces an area of 6 or 7 square miles, consisting of igneous intrusions of late or post-Carboniferous age. These rocks overlap the Millstone Grit series on the north and north-east, and rest unconformably on the Carboniferous Limestones, occupying the position of the Upper Limestone. They are also found piercing through the limestone and burning it.

Fine exposures are obtained on Gass Water and Bello Water, as the same stream is called nearer its confluence with the Glenmore Water to form Lugar Water. Good sections have been laid open in the Ayr & Cumnock Railway cutting near the viaduct over Glenmore Water at Lugar; but the best of all are those on Glenmore Water, in and below Cubb's Glen, and in the Glasgow & South-Western Railway cutting at Blackfauld, about 2 miles south of Lugar. These will be referred to in detail.

IV. General Description of the Area.

On Gass Water the igneous rocks are chiefly ordinary basalt and dolerite, tending to approach picrite. They are extremely weathered and much cut by joint planes. Sometimes they

Digitized by Google

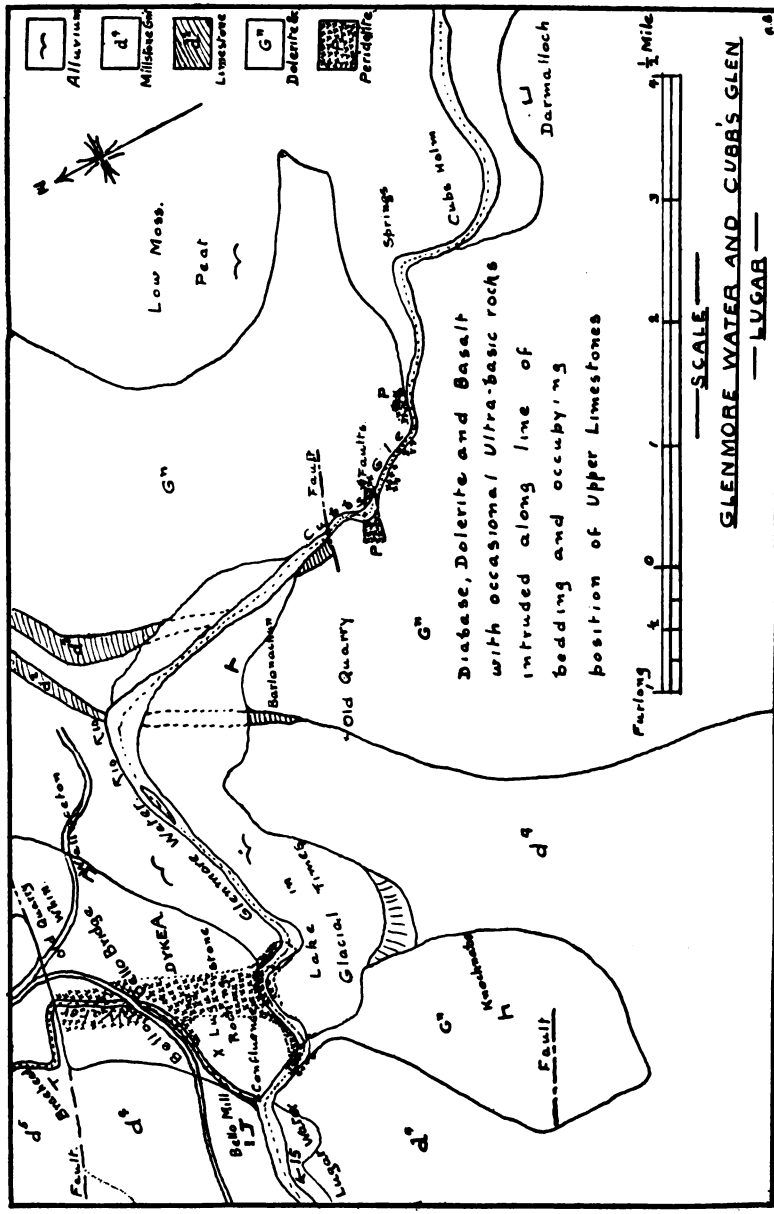


Fig. 1.

Digitized by Google

contain very large phenocrysts of prismatic augite, usually more or less altered into chlorite. On Bello Water the rocks gradually assume a more basic nature. For several hundred yards above the Bello Bridge segregated masses of peridotite and picrite are laid bare by the stream. Hornblende cleavages can be distinctly seen in a hand specimen, without the use of a lens, and the decomposing mineral shows beautiful lustre mottling caused by schiller planes. The crystals can be picked out by the hand on fresh surfaces. The rock has rather a gritty appearance, and the decomposition is so great that it is difficult to trace the transition to less basic varieties. Just above Bello Bridge, on the south side of the Muirkirk road, there is a steep mural cliff of peridotite standing over 20 feet high. This is a cross section of a large, coarsely crystalline dyke which crosses here. It probably begins on the other side of the road, in the vicinity of Bello Water, as evidenced by the contour of the ground and the nature of the soil. For convenience this will be called *Dyke A*. Following down Bello Water from here, we find this dyke passing by a series of almost insensible gradations, through picrite and doleritic picrite, to an olivine basalt verging on picrite. At one part in the bed of the stream is a variety with very large phenocrysts of augite, exactly the same as is found on the other side of the dyke, and which will be described later. These rocks appear to be in reality parts of Dyke A, being intrusive sheets or sills which have cooled more rapidly than the main dyke. Near the edge of the sill, and almost at the confluence of the waters, the rocks assume the columnar structure characteristic of basalt. This structure, together with rock cleavage and denudation, probably to a great extent accounts for an interesting feature found here, which is popularly known as the "Lugar rocking stone." On the bank to the south is a four-sided vertical column in the process of weathering off the main sheet. The stream itself has also taken considerable part in denudation between that bank and the supposed Druidical monument, as it has changed its course from there to its present bed on the opposite side of the structure.

On the high ground between the two streams the Ayr & Cumnock Railway passes through a cutting, then over the

Digitized by Google

Glenmore Water by a large viaduct just above the junction of the streams. The cutting exhibits on both sides fine sections of Dyke A. A characteristic feature of this rock seen in all exposures is its spheroidal weathering. When a surface has been exposed for a time it assumes a greenish colour with a very faint tinge of yellow, and becomes granular, loose, and crumbling. The colour is due to the serpentinisation of the olivine. Certain portions of the rock, however, decompose less, owing to greater hardness, and assume a spherical form by reason of the weathering in their vicinity. When this is carried to the extreme we find an unweathered boulder, representing the hard centre of spheroidal weathering, surrounded by a strong soil of decomposed peridotite. A fresh chip can only be obtained from such boulders, and a fresh fracture has a dark greenish black tint.

Crossing the railway a few hundred feet nearer Cronberry Station there is an intrusion, probably a dyke, of less basic rock. Beds of much metamorphosed, micaceous sandstone occur beside it. There has also been considerable faulting. On one side of the cutting a vein of barytes can be seen in the sandstone. Such veins are fairly plentiful in the district, and usually run parallel to dykes. There is one in contact with sandstone just below Bello Bridge, on both sides of the Muirkirk road, and the Bello Water carries down a large number of boulders of barytes from veins in its upper reaches.

Below the confluence for a considerable distance the rocks traversed by the "stately Lugar" are mainly Carboniferous Sandstones and Shales. The sandstone varies from greyish white to brown, but usually is very ferruginous. Near Lugar the Millstone Grit is represented as coarse white and yellow friable sandstones. From Lugar to near Old Cumnock Station the river flows softly through a peneplain.

Starting now at the junction of the streams, let us proceed up the Glenmore Water. On the near side of the railway viaduct we come on the outer edge of the sill from Dyke A. It is very compact, but gets coarser in grain as we proceed inwards. Large prisms of augite are again conspicuous, and also an actinolitic hornblende. Beneath the viaduct there is perhaps the finest section, showing the decomposition of ultra-

Digitized by Google

basic rock into numerous, comparatively unaltered, hard, rounded or elongated, pebbles and boulders in a matrix of partially formed soil. This is a most noticeable feature all over the area wherever the most basic varieties occur. It is again well seen in the middle of the glen, and also at the very top. Immediately above the viaduct, on the right bank, there is a remarkably fine exposure of peridotite. It is the best to be seen in the whole district, and is a steep vertical wall of Dyke A. The stream runs close to it. The greatest depth of the section is about 66 feet of clear rock, with about 30 feet of soil on the top. Here and in other sections there are numerous veins of acid material, sometimes with a thin outer layer of calcite, running in wavy lines in an approximately vertical direction. For 300 feet the section is entirely peridotite or picrite, and on the east margin, as we go further up, it shades in the bed of the river into a porphyry, containing long black prisms of augite, measuring on the surface of some specimens over $2'' \times \frac{3}{16}''$. The aqueous action has at this point produced a columnar weathering, which is similar to, but better seen than, that on Bello Water on the other side of the dyke. The rocks stand in numerous short vertical columns in the river bed. On the left bank opposite the dyke the texture shades into a more compact variety of dolerite. Few exposures of note are seen in the direction of the continuation of the dyke. From here to the foot of Cubb's Glen, about half a mile further up, the river flows through a flat alluvial meadow, hemmed in on all sides by drift banks, which converge at the viaduct. This plain may have been the bed of a lake in glacial times. The outlet for ice and water would be at the viaduct. The floor of the supposed lake is not wanting in evidence. It is of a sandy nature all over, and the sections exposed by the river show at some parts about 10 feet of sandy boulder clay beneath a foot or so of soil. I have found Arctic shells in the clay here. Towards the upper extremity there has been a great deal of local earth movement among the sandstones, clays, and shales. The river has, in several instances, changed its course there. The Millstone Grit is represented by coarse white and yellow friable grits and sandstones, with seams of fireclay and thin coal.

Digitized by Google

Where Wallaceton Burn joins Glenmore Water the igneous rocks again come in as a narrow tongue or dyke, which begins at a fault a short distance up the burn. The dominant mineral is augite, again in long prisms, altering into chlorite. The rock might be called a diabase porphyry. On each side of this intrusion are beds of Carboniferous Limestone. The first one is not seen from the river till it appears in an old quarry on the other side of the meadow. The second probably crosses obliquely, and is the limestone which comes in at the foot of the glen, from where it rises up the left bank as far as the first fault in the glen. It rises from under the sandstones, and is fossiliferous. The dip is about 10 degs. It has been very much burnt, pierced, and distorted by the lava intrusion. The fossils in it and the associated shales include specimens of encrinites, trilobites, Productus, Spirifera, Euomphalus, and various mollusca.

O Cubbs, what utter changes hast been thine!
  Long, long before thy infant stream could creep,
There where thy lowly plants and trees recline,
Vast monarchs of the past did nobly twine;
  There where thy paltry waters meekly sleep,
  The great sea bed upheld the roaring deep,
And lovely creatures, bold and passing strange,
Did in their myriad forms the ocean range.—R. B.

A short distance up the glen the limestone is found at one part to have been lifted up with the igneous rock, and shut in on both sides. Another section shows the band of limestone lying between two igneous sheets or sills of compact basaltic rock with a reddish fracture. The colour is due to iron-stained felspars. We have now fairly entered the glen, which is one of the finest in Ayrshire. The bed of the river is thickly strewn with pebbles and boulders.

Some of the huge blocks of stone weigh several tons. Agates are commonly found among the pebbles, having been brought down from the sources of the Glenmore, where they occur *in situ*. Many great boulders of peridotite are torn away here and carried, not only into the Lugar Water, but with it into the River Ayr. I have found them in the Water of Ayr near where the Lugar enters at Barskimming, and peridotite is an unmistakable rock. At the bend of the stream in the glen are two faults, in addition to the one already mentioned. They

Digitized by Google

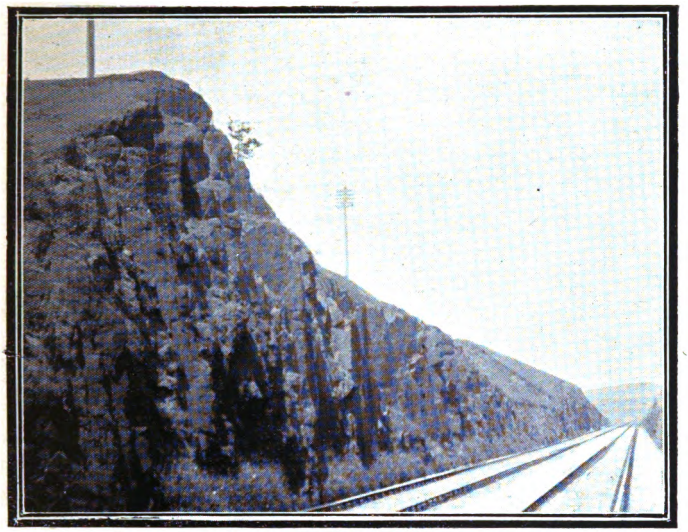


Fig. 1.—Diabase Rocks in Blackfauld Cutting, Cumnock.

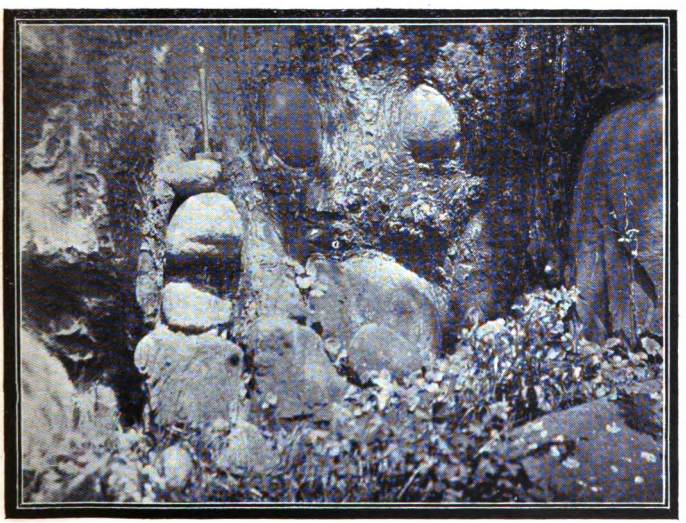


Fig. 2.—Advanced Rock Weathering, Cubb's Glen, Lugar.

Digitized by Google

Digitized by Google

occur one on each side of a high bank of weathered rock resembling a dyke, through which the river has cut its way. The upper one brings in sandstone in the bed of the stream. At this part the gorge has a steep vertical wall about 53 feet high, with 7 or 8 feet of sloping rock on the top, and as much again of soil. The characteristic weathering is particularly well shown. This ravine appears to be a post-glacial formation. The rest of the glen consists of igneous rocks, supplying all gradations from peridotite to compact olivine dolerite, and at Darmalloch we emerge on a wide open plain of boulder clay.

The Glasgow & South-Western Railway cutting at Blackfauld lies 2 miles south-west from Cubb's Glen. For several hundred yards on each side there are fine sections of all varieties of lava. There are a number of sills and dykes of ultra-basic rock in the main mass of dolerite. Near the north end, and on the east side of the cutting, there is a good example of a peridotite sill. It is about 2½ feet thick, and is enclosed above and below by less basic rock. The line of demarcation is very distinct in this case, owing to the more greenish colour and spheroidal form of the weathered surface, together with its greater decomposition. This sill appears, therefore, to be of later age than the surrounding rock.

Towards the south end there is a large basic mass with a width of about 12 feet. It is seen on both sides, and has a vertical height of about 20 feet. There are other irregular segregations of peridotite and picrite.

On Avisyard and Coila Hills, about 2 miles east of Lugar, several "whin" quarries have been opened in the same intrusions, but none of them show any ultra-basic tendency. The rock is a very much decomposed dolerite, with little olivine, and a great deal of cloudy felspar.

V. Soil.

The ultimate decomposition of the more basic rocks produces in this district a characteristically light brown clayey soil, which does not seem to be very productive. These rocks are probably first attacked by bacteria, after which mosses and lichens gain a hold. They are followed by such colonisers as *Asplenium ruta-muraria* and *Asplenium trichomanes*, but it

Digitized by Google

is a long time before vegetation is common. The rocks are bare and singularly barren in appearance. This is probably due to the excessive amount of magnesia liberated from the serpentinous products of olivine. Hornblende and augite, however, neutralise the effect considerably, as they give a brown ferruginous sandy loam. Careful observation can readily distinguish the vegetation on decomposed diabases from that on the peridotites. The former and all shades, except the very basic, give a good loam.

VI. Petrographical Description.

A. Minerals.

In beginning a petrographical examination of the rocks of the area, it will be convenient, first of all, to describe the general characteristics of the minerals, as exhibited in a large number of rock slides.

Olivine.—This mineral is very plentiful in most of the rocks. It has a strongly pitted surface, which would ultimately reduce it to the granular form. There are crystals with orthorhombic outlines, grains, and granular aggregates. Some sections contain perfectly idiomorphic crystals. In all there are numerous cracks, often resembling trees with green wavy branches and stems. In the peridotites the network thus formed is exceedingly fine. Magnetite, as well as green serpentine, develops along the cracks. The yellow variety of serpentine usually stands out by itself in the centre of a green area of more decomposed olivine. In many slides the yellow portions have a micro-spherulitic structure, consisting of radiating fibres. The green variety of serpentine is often tufted. Magnetite is common on the rim. These colours are due to the oxidation of the iron. When olivine changes into serpentine there is an absorption of about 13 per cent. of water, and a proportion of magnesia separates out as a carbonate; silica may sometimes be separated out from the displacement by carbonic acid. Many of the olivine crystals are rounded, with the typical dark outline. Chromatic polarisation is bright, and double refraction strong. The crystallisation of the olivine has in all cases preceded that of augite and hornblende.

Digitized by Google

Hornblende.—This is much more abundant in the peridotites than any of the other rocks. It has a strongly marked pleochroism according to the following scheme:—

α = pale yellow brown.
β and γ = rich dark brown.

Some sections are not pleochroic; for example, those which are approximately parallel to the orthopinacoid (100). They contain the β and γ axes. The colour of these slices is a rich red or reddish brown. In all but the peridotites, hornblende seems to be an alteration product, usually appearing as an actinolitic variety with faint pleochroism. It rarely or never occurs in characteristic six-sided form.

Augite is scarce in the peridotites, but very abundant in those rocks afterwards described as diabases. Eight-sided crystals are common, with cleavages intersecting at 93 degs. in sections at right angles to the "c" axis. The columnar habit is most frequent. Such crystals may be over 2 inches in length. They are usually traversed by thick irregular cracks, and in some cases the crystals appear to have been faulted in a direction at right angles to the length. Others, again, are bent. There must have been very considerable strain action causing mechanical deformation. Mr. Macnair describes a similar phenomenon (*Trans.* Geol. Soc. of Glas., vol. xiii.), but in the case of these rocks I have observed signs of strain action affecting the felspars also. It is probably true, however, that, in general, the movement causing deformation took place shortly after the crystallisation of the augite. The colour is usually pink to purplish. Pleochroism is rare. Zonal and hour-glass structures are occasionally noticed. The ophitic structure is very common all through these rocks. In some sections the augite seems to act as a groundmass. There is abundant decomposition into chlorite.

Plagioclase Felspar.—There is a tendency towards an idiomorphic columnar habit. The cleavages are well defined. Twinning is common, and is referred to under the diabases. Plagioclase is either absent or very cloudy and decomposed in the ultra-basic rocks.

Biotite.—This mineral occurs in small pleochroic needles and irregular flakes. It is generally in association with augite, and seems to be in many cases a decomposition product.

Digitized by Google

Iddingsite has the general appearance of a brown mica. It has not been very definitely identified in non-olivine rocks of the area. It is usually in association with magnetite, and is recognised by its characteristic deep blood-red colour. It occurs in the olivine basalts and some of the dolerites, but not in peridotite or picrite. The form is irregular, and unlike the needles and prisms of biotite.

Quartz.—This is common in the diabases. When it occurs interstitially it is difficult to decide whether it is original or a decomposition product. In some cases it not only encloses apatite, but seems to form an intergrowth with the felspar. The latter is not very decided, however. It is very probably not all secondary.

Analcite or Analcime has the composition Na. Al. Si_2 O_6 + H_2O. It is very frequent in the groundmass of the olivine basalts and dolerites, in which cases it is probably a primary mineral, which has been produced by the presence of considerable quantities of soda and water vapour, held under pressure during the crystallisation of the magma. It sometimes shows a weak double refraction, due to loss of water and consequent change in molecular structure. The colour is usually white or greyish. Decomposition begins round the edges. In many cases it is most likely, first of all, a decomposition product of plagioclase felspar, but in others it is almost certainly original.

Apatite is very abundant in all the dolerites and diabases. It is often invisible, except under cross nicols. The needles are sometimes very long, and may be seen projecting into any other constituent, denoting its early formation in the magma. A number of crystals frequently occur together in a nest.

Iron Ores.—These are both original and secondary. They are comparatively scarce in ultra-basic slides, but very abundant in all others. Hæmatite, magnetite, ilmenite, and titanoferrite are all found.

Groundmass.—This consists variously of decomposed analcite, micro-pegmatite, chloritic products, serpentinous material or diffused, indistinguishable alteration products. Combinations of these may exist. Some of the more compact rocks have hardly any groundmass.

Structure.—The crystallisation of the felspar has usually preceded that of the dominant ferro-magnesian constituent.

Digitized by Google

Augite is moulded round laths of felspar, often radiating from a centre. Occasionally the augite in the form of grains is embedded in a plexus of felspars, forming what Professor Judd has called the "granulitic" structure. He considers it due to movement towards the end of the process of consolidation. Olivine is always idiomorphic towards augite.

B. Microscopic Rock Sections.

It should be clearly pointed out that, in the description of rocks which now follows, the term "diabase" is used in the sense in which Harker uses it, to represent a pyroxenic rock, intermediate or basic. It has no reference to the age of the rock, as with German petrographers, and at the same time is not merely a decomposed dolerite, in which sense it is used by some British geologists. The rocks described in this area as diabases seem to me to be too holocrystalline to be correctly termed dolerites. They differ from the normal or typical diabase only in the fact that augite commonly has crystal outlines.

In each case description No. I. is *macroscopic* and No. II. *microscopic*.

Hornblende Peridotite. Bello Bridge. Dyke A.

I. Dark-coloured greenish-black holocrystalline rock, composed of large allotriomorphic crystals of hornblende, and idiomorphic crystals of olivine, in a more or less serpentinised state. The dark interstitial matter is essentially olivine. This is a very heavy rock. The specific gravity varies from as low as 2·9, in much serpentinised specimens, to 3·2 in fresh ones.

II. (1) *Olivine*.—Very abundant, colourless, with numerous irregular cracks and anastomosing veins; from which and the periphery starts the process of alteration into two different decomposition products, the one light green serpentine predominating, and the other yellow or pale yellow. The latter colour is probably due to the presence of chromium in the olivine; alteration in some cases along cracks to magnetite. Crystals hypidiomorphic, with pitted surface; they may be

Digitized by Google

fresh or altered, and are often enclosed in hornblende; pœcilitic structure common; it is best seen in highly decomposed sections, in which granules of olivine are embedded in the schiller planes of the hornblende; much granular olivine forming beautiful networks.

(2) *Hornblende.*—Abundant; light brown to dark brown or reddish brown; typical intersecting cleavages; intense pleochroism, especially in lighter varieties; very ragged in form; capriciously arranged, deep reddish-brown patches in many sections; crystals darker in colour when cut so as to show only one cleavage; alteration along cleavage planes into magnetite; magnetite, fresh olivine, green or yellow serpentine may be enclosed; schillerisation is more noticeable in decomposing sections.

(3) *Augite.*—Granular; light coloured; not very plentiful, except in the groundmass; a few small crystals, with no definite outline; grains often surrounded by hornblende.

(4) *Magnetite and Iron Ores.*—Not very abundant; original crystals straight-sided; form usually irregular when an alteration product of hornblende or olivine; often enclosed in serpentine and hornblende.

Picrite.

I. This rock is lighter in colour when seen in a mass than peridotite, and the specific gravity is reduced. Where it is acted on by streams it has a lighter greenish tint, and is polished, with lustre mottling. A typical specimen is somewhat rare in the district.

II. The characteristics of the minerals are very similar to those of peridotite. There is a decrease of hornblende and an increase of augite. Decomposition of the olivine is less rapid. Plagioclase felspar, probably labradorite, appears as a subsidiary constituent, but the crystals are too dull, cloudy, and partially kaolinised to be readily identified. Biotite is present in some sections, as a subsidiary mineral.

Olivine Basalt approaching Picrite.

I. Rock of medium texture; olivine still prominent; fracture of a lighter greenish colour.

Digitized by Google

II. (1) *Olivine.*—Abundant, but not much decomposed, showing that, in general, the alteration is less rapid the further the type is removed from peridotite; phenocrysts are common, as well as the more granular form.

(2) *Augite.*—Mostly granular, but also in flakes; alteration into chloritic products consisting of a hydrous silicate of magnesia, alumina, and iron protoxide, with a yellow-green colour.

(3) *Hornblende.*—Not very plentiful and usually absent.

(4) *Felspar.*—Very abundant, as plagioclase and probably labradorite; form prismatic, but crystals often much kaolinised. The groundmass contains plagioclase felspars at the acid end of the series, showing a gradual increase of basicity as we pass inwards. Granules of augite are frequently enclosed.

(5) *Biotite.*—In small quantity, as light reddish pleochroic prisms.

(6) *Iron Ores.*—Both magnetite and titaniferous iron are found; magnetite is largely an alteration product of augite.

(7) *Iddingsite* seems also to be represented.

Olivine Basalt.

I. Compact, even-grained, hypidiomorphic rock.

II. This rock is very similar to the last, but is more compact and finer in grain. It contains less olivine on the whole, and more plagioclase and augite. Many of the olivines are six-sided; some crystals show schiller structure. Augite granules are enclosed in felspar with a decreasing basicity outwards. Analcite is fairly common in small crystals and as part of the groundmass. In the latter it is much decomposed. Biotite occurs in grains, and pleochroic prisms, but iddingsite is more common, and is usually in association with magnetite, both probably altering from olivine. Apatite is seen in some slides, but it is not so frequent as in the diabases.

Diabase.

I. Coarse-textured, holocrystalline rock, with very long augites, measuring as much as 2 inches, and usually decomposing into greenish products.

II. (1) *Olivine.*—Present only in medium quantity in those described as olivine diabases; bright yellow, rounded crystals,

Digitized by Google

often with border of magnetite; decomposition along cracks into magnetite and green serpentine; frequently enclosed by augite.

(2) *Augite.*—Beautiful eight-sided, idiomorphic, purplish or pink crystals, with good cleavages; also very long prismatic crystals beginning to alter into green chlorite at edge, many developing cracks along both cleavage planes, which appear to be filled with iron ore; long crystals occasionally bent; seldom pleochroism; grains of magnetite enclosed.

(3) *Hornblende.*—In long, fibrous, actinolitic, pleochroic crystals, possibly altered from augite.

(4) *Plagioclase.*—Long prisms, with strong tendency to idiomorphism and columnar habit; albite twin lamellation very common; occasionally Carlsbad twinning, but seldom pericline; zone structure somewhat rare, and usually in crystals towards the acid end.

(5) *Biotite.*—Brown, irregular crystals and needles; somewhat rare if olivine is present; shows alteration into magnetite; occurs enclosed in augite and altered from it.

(6) *Analcite.*—In small quantities; common in the groundmass.

(7) *Iron Ores.*—Magnetite, titaniferous ore, and leucoxene.

(8) *Apatite.*—Numerous needles capriciously distributed in the groundmass.

Analcite Diabase or Teschenite.

I. Coarse-textured, greenish-grey rock, with white patches of analcite, and occasional zeolites of calcite; distinctive speckled weathered appearance.

II. (1) *Augite.*—Considerably diminished in quantity, and much decomposed into greenish, pleochroic, chloritic products; a few idiomorphic crystals sometimes enclosing hornblende; some fibrous crystals.

(2) *Analcite.*—In considerable quantity as clear interstitial patches, often decomposing on the border; it forms an isotropic groundmass, or shows feeble double refraction; it is probably to a great extent secondary; the crystals show air bubbles.

(3) *Plagioclase Felspar.*—Abundant; prismatic.

Digitized by Google

(4) *Biotite.*—Light reddish-brown, pleochroic needles and crystals, showing good cleavages. The pleochroism is red to green.

(5) *Iddingsite* is very probably represented also.

(6) *Iron Ores.*—Titanoferrite, and its alteration product leucoxene, occur in characteristic ragged outlines.

(7) *Apatite.*—Fairly common; in needles.

Quartz Diabase.

I. Fairly coarse-textured, speckled rock; quartz easily recognised in hand specimens.

II. (1) *Augite.*—Light purplish idiomorphic crystals, mostly prismatic; very many irregular, partially decomposed crystals, in greenish chloritic material, with a beautiful tuft structure, especially in the Blackfauld varieties. It encloses both quartz and felspar in the Cubb's sections.

(2) *Felspar.*—Long, fibrous prisms of plagioclase, sometimes much kaolinised; radiating, ophitic structure; many rhomboidal crystals in Blackfauld slides.

(3) *Quartz.*—Clear, colourless crystals, which to some extent fill the interstices; dot-like inclusions, crowded near the centres of the crystals; numerous needles of apatite, often only visible under cross nicols, sticking in radial groups into the quartz or entirely enclosed by it. There is nothing to indicate that this mineral is not an original constituent, though it occurs as an inclusion in augite, along with ophitic plagioclase.

(4) *Iron Ores.*—Magnetite or other varieties are usually present.

(5) *Apatite.*—Very abundant in all sections.

Olivine Dolerite.

I. Compact rock with reddish fracture, showing brown iron-stained felspars, and small phenocrysts of olivine.

II. (1) *Olivine.*—This mineral occurs as phenocrysts, and also in the granular form; usually much altered.

(2) *Augite.*—Almost entirely altered into green, chloritic products, and also probably serpentine. Zeolitic decomposition products are common in the interstices, and are slightly pleochroic; rosette chlorite.

Digitized by Google

(3) *Felspar.*—Much kaolinised and iron-stained. It occurs earlier than the augite in the ophitic structure, and later in the granulitic structure; a few lath-shaped crystals with multiple twinning. The spherulitic chlorite often includes laths of this mineral.

(4) *Magnetite.*—Very plentiful; typical ragged form.

(5) *Biotite.*—Pleochroic flakes associated with magnetite; also small prisms.

(6) *Apatite.*—Common in the groundmass; often not visible except under cross nicols.

Note.—There are also sections of dolerite and basalt without any olivine at all.

VII. General Remarks.

The Lugar peridotites and picrites resemble fairly closely the augite picrite of Inchcolm, except for the predominance of hornblende instead of augite; in the case of the Lugar rocks augite is less plentiful in the ultra-basic varieties than in those shading to diabase and dolerite. The ferro-magnesian mineral is almost entirely altered in most sections of the Blackfauld diabase, and plagioclase is exceedingly abundant in many sections. Quartz diabases occur at various parts all over the area. They approximate closely to similar rocks from the Kilsyth district. Those sections described as analcite diabase resemble the group called "teschenite" by Hohenegger. They are intrusive, and consist mainly of augite, brown hornblende, plagioclase, apatite, and analcime. A rock of this kind is found at Car Craig, in the Firth of Forth. Harker describes it as being rich in a purplish-brown, pleochroic augite, and containing altered felspar, analcime, and other zeolites, iron ores, and brown mica (probably secondary). It has points in common with the picrite of Inchcolm. A similar diabase forms a sill at Dippin, in South Arran. It is noticeable in the rocks of the Cumnock district that analcite is always more plentiful in the absence of olivine.

The various descriptions of microscopic rock sections already given are typical, rather than the characteristics exhibited in any one slide. They have been deduced from the examination of a number of sections taken at various parts all over

Digitized by Google

the area. Each chip was carefully located often to within a few inches, an exact note of this being taken when it was collected. A reference number was given to each, the date being also noted, along with the number. The microscopic slides were all made by the writer. No fewer than eighteen were found necessary in the immediate vicinity of Dyke A. These facts will serve, in some measure, to justify the conclusions which will shortly be drawn.

The following table contains a summary of the constituents of the more important rock sections. It must be distinctly understood that the symbols as to the abundance of the various minerals can only be taken as approximate. The table shows that, as we pass outwards from Dyke A along the associated sills to the western edge of the intrusive mass, all varieties of rock are met with, from hornblende peridotite to olivine basalt; again, in passing to the eastern edge, we meet with various shades of diabase in which the proportion of olivine becomes sensibly less. Quartz diabase has not been met with exactly here, but it certainly occurs on the edge of the intrusion at Cubb's Glen, as well as in other parts of that intrusion.

Some of the basic intrusive dykes of the Highlands show a decided variation in basicity in the same mass. Marginal modifications have frequently been produced. In "The Geological Structure of the North-West Highlands of Scotland" a case is mentioned (page 185) in which a dyke, though of more basic composition than the "green dykes," is yet, in its marginal parts, composed of ordinary hornblende schist.

VIII. Summary and Conclusions.

The foregoing paper describes the occurrence of terrestrial peridotites in the Lugar and Cumnock district igneous intrusions, resembling perhaps most closely, in structure and composition, the Assiderite type of extra-mundane, stony, meteoritic peridotite. When these rocks are traced outwards along intrusive sills and sheets their petrological affinities proclaim a genetic relationship. A petrological examination of the rocks of this area shows that peridotite and picrite may pass by insensible gradations into a compact olivine basalt. The intrusion at Bello Bridge is en-

Digitized by Google

SUMMARY.

Dyke "A" and Associated Intrusive Sills, Rocks in Cubb's Glen and Blackfauld Cutting.

No.	Occurrence.	Constituent Minerals (Original and Secondary).									Ground Mass.	Spec. gravity of rock.	Name of Rock.
		Ol.	Aug.	Hnb.	Bi.	Pl. F.	Fe.	Ap.	An.	Q.			
1	Western Edge	A.	A.	...	S.	A.	A.	S.	S.	...	Diffused alteration products.	...	Olivine Basalt.
2	near Lugar	A.	A.	...	M.	A.	M.	M.	...	...	...	...	Olivine Basalt, approaching Picrite.
3	inwards	A.	A.	S.	S.	S.	S.	...	...	...	...	2·89	Picrite.
4	to Dyke A and	V.A.	S.	A.	...	...	S.	...	...	...	Granular Ol., Aug. and Serp.	2·9 to 3·2	Hornblende Peridotite.
5	outwards	M.	V.A.	...	S.	A.	M.	S.	...	...	...	2·78	Olivine Diabase.
6	to	V.S.	V.A.	V.S.	A.	V.A.	A.	V.A.	M.	...	Decomp. Analcite.	2·78	Augite Diabase.
7		...	V.A.	M.	M.	M.	A.	A.	M.	...	...	...	Diabase.
8	Eastern Edge.	...	M.	...	M.	V.A.	A.	S.	V.A.	...	Decomp. Analcite	2·7	Analcite Diabase.
9	Cubb's Glen, -	...	V.A.	V.S.	V.S.	A.	S.	V.A.	...	A.	Viridite.	...	Quartz Diabase.
10	Blackfauld Cutting, - -	...	A.	S.	...	V.A.	V.A.	V.A.	...	V.A.	...	2·75	Quartz Diabase.
11	Cubb's Glen (left bank),	M.	M.	...	M.	A.	V.A.	S.	...	...	...	...	Olivine Basalt.
12	Barlonachan, -	S.	A.	...	S.	A.	A.	M.	...	...	Diffused alteration products.	...	Dolerite.
13	Blackfauld, -	...	M.	...	...	V.A.	A.	M.	...	...	Almost glassy.	...	Dolerite.

Note.—A comparative meaning is to be attributed to these symbols only when read in a vertical direction—
V.A. = Very Abundant; A. = Abundant; M. = Medium; S. = Scarce; V.S. = Very Scarce.

Digitized by Google

tirely basic, and seems to be younger and distinct from that containing Cubb's Glen and Blackfauld Cutting, which is more acid, and contains quartz; and the ultra-basic rocks associated with the latter have probably been intruded about the time that the main mass at Bello Bridge was formed.

The general deductions from the petrographical researches, especially those carried out at Dyke A, and its associated intrusive sills, go to show that, even in the same mass of eruptive rock, there may be very great differences in chemical composition. This points to some separation of the constituents before consolidation. The peridotites represent a distinctive phase of the magma, in which the magnesia was greatly concentrated. They are segregations produced by the magmatic differentiation of lavas come to the surface. The rock mass, termed Dyke A, is really a segregation, and not in the strictest sense a dyke, though having the general appearance of one. At the same time, the rocks in its immediate vicinity have all the appearance of being sills derived from it. They are less basic, and, having cooled quicker, are more compact and basaltic. The whole phenomenon can be best studied near Bello Bridge, Lugar. In the rocks associated with Dyke A there appears to be a decrease of basicity towards the edges. The change is occasionally irregular, but oftener is very gradual. Assuming that the edges of the mass were the first to cool, this would appear to be a contradiction of the principle that the most basic materials solidify first. It is probable, however, that the sills or edges of the intrusion have been pushed out from a more acid interior reservoir, after the main mass of peridotite had been intruded, and had undergone partial cooling and segregation. The most basic material was therefore the first to be discharged. Then came the more acid, which fused with the first intrusive mass at its edges, while differentiation was still going on. In the Blackfauld cutting there is a sill of peridotite which seems to have been pushed into the dolerite or diabase above and below. The peridotite, therefore, appears to be of later age than the surrounding rocks in this case.

Returning to the question of differentiation; in the case of the picrite of Bathgate the rock shades upwards into a variety

Digitized by Google

in which heavy magnesian silicates are to a great extent replaced by felspars, so, in this case, the phenomenon is best explained by an actual differentiation of the substance of the magma, whereby the more basic and more acid constituents are separated into different portions of the mass, producing marginal modifications in the structure and composition. The chief condition determining the separation of the constituents is complex, but would appear to be a sinking of the temperature. The crystallisation would, at the same time, be modified by conditions of depth, temperature, and movement, due to renewal of eruption or other causes.

The whole phenomena in the Lugar district may therefore be referred to segregation in a viscous magma, and movements in the partially differentiated mass.

EXPLANATION OF MAP AND PLATES.

Map of district near Lugar, showing the position of dyke A and other segregations of peridotite on Glenmore and Bello waters and in Cubb's glen.

PLATE X.

Fig. 1.—Section exposed on right bank of Glenmore water at head of Cubb's glen. It resembles boulder clay, but is in reality a fine example of the characteristic spheroidal weathering of basic rock. Each boulder is surrounded by concentric shells, which gradually merge, by decomposition, into soil.

Fig 2.—Diabase rocks in the Blackfauld cutting, Cumnock. They contain sills and irregular intrusions of peridotite.

PLATE XI.

Fig. 1.—Hornblende Peridotite, × 7. From mural cliff at Bello Bridge (dyke A), Lugar. The large six-sided crystal in the centre is olivine. It contains numerous cracks, along which green serpentine is forming. The two dark spots are magnetite. The crystal immediately to the left of it is hornblende, enclosing small pieces of serpentine. To the north-east of it is a piece of yellow serpentine. The dark matter is mostly green serpentine, and there is a little granular augite in the groundmass.

Fig. 2.—Olivine Basalt approaching Picrite, × 25. From Glenmore water near Lugar viaduct. The minerals include olivine, cloudy felspar, augite, and magnetite.

Fig. 3.—Olivine Basalt, × 7. From near confluence of Glenmore and Bello waters. The large crystal is olivine. Some of the felspars enclose granular augite, forming the granulitic structure. The other minerals are

Digitized by Google

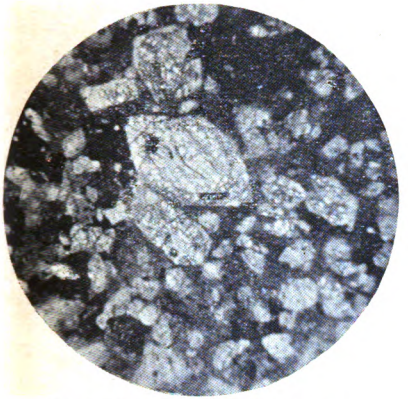


Fig. 1.—Hornblende Peridotite, × 7.

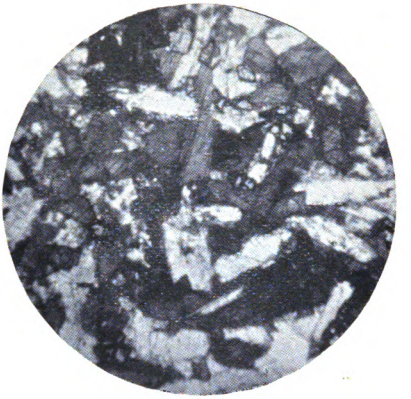


Fig. 4.—Diabase, × 7.

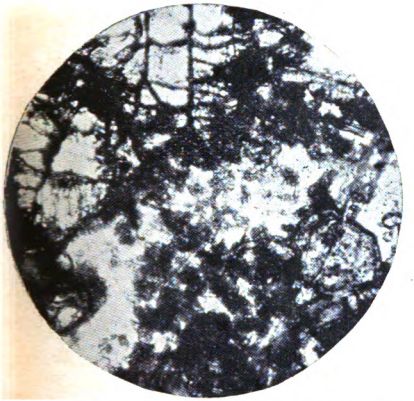


Fig. 2.—Olivine Basalt approaching Picrite, × 25.

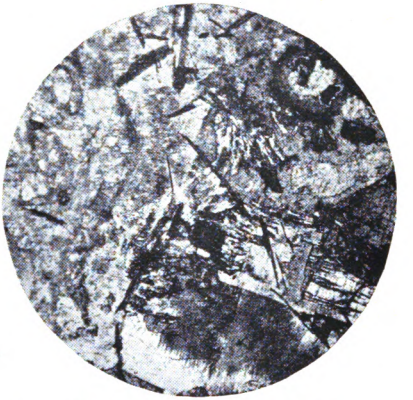


Fig. 5.—Analcite Diabase, × 25.

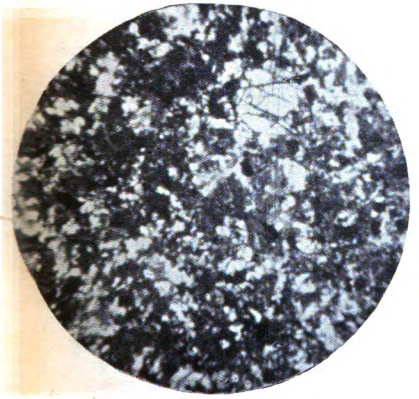


Fig. 3.—Olivine Basalt, × 7.

Fig. 6.—Quartz Diabase, × 25.

Peridotite and Associated Rocks.

Digitized by Google

Digitized by Google

iron ore, a little analcite, and iddingsite. This section and the two preceding ones form a series.

Fig. 4.—Olivine Diabase, × 7. From eastern edge of intrusion, in bed of Glenmore, and close to dyke A. There are small rounded crystals of olivine in the upper half of the section. Dark magnetite occurs in the extreme north-west, with a clear crystal of felspar projecting into it. The latter is cut at right angles by a crystal of purplish augite. The crystal in the fourth quadrant thus formed is analcite. The groundmass contains apatite.

Fig. 5.—Analcite Diabase, × 25. From same locality as section in Fig. 4, but a few feet nearer the edge of the intrusion. The large crystal to the south is analcite. It shows the characteristic decomposition on the edges. The section shows augite, plagioclase, laths of biotite, apatite, and magnetite. This section and all the preceding ones are from the same intrusive mass at Bello Bridge, Lugar.

Fig. 6.—Quartz Diabase, × 25. From Blackfauld cutting on G. & S.-W. Railway, Cumnock. The large crystal of plagioclase felspar to the south shows the intersecting cleavage planes by its outline. To the north is a peculiarly shaped crystal of quartz enclosing eight needles of apatite. The latter is prominent in the chloritic groundmass. Iron ore is also present.

I have to acknowledge my indebtedness to Mr. S. Fingland and Mr. R. Dunlop for assistance in preparing the negatives of the microphotographs illustrating the paper.

Digitized by Google

No. XVIII.—Discovery of Upper Coal Measure Fossils in Ayrshire. By John Smith.

[Read 9th April, 1908.]

On 9th April, 1907, I examined some débris which had been put out from a pit sinking between Auchenleck and Ochiltree, and found some of it crowded with the remains of plants. As this sinking is to be a deep one, I advised Mr. Clough, of the Geological Survey, to have an examination made of all the material brought up. I am glad to say that this is being done, so that in two or three years hence we will likely have one of the best records of rocks and fossils from any sinking in the Coal Measures, at least in Scotland.

The material put out was quite different from anything I had seen from a pit sinking, and in no open section in the district are similar rocks to be observed, the strata in this locality being thickly covered with shelly drift.

At that time the sinking was about 66 fathoms, and I noted the following varieties of rocks on the bing:—

Rocks.

Brown mudstones, crumbling on exposure.

Bright and dull-red mudstones, crumbling.

Light grey mudstones.

Dirty yellow mudstones.

Purple mudstones, with yellow blotches, some of the blotches with minute purple nodules.

Hard, brown kingle.

Purple sandstone, with globular parts, where the colour had been discharged.

White sandstone, with minute black spots.

Dark purple sandstone, with irregular white blotches; a very fantastic-looking rock.

Brown sandstone, with minute spots.

Dark grey sandstone.

Sandstone, with carious hollows.

Hard, irony-looking band, 7 inches thick, but probably with very little iron.

Digitized by Google

Grey sandy shale, with red nodules.

Fine-grained, grey limestone nodules, with quartz grains and spirorbis.

Plant rootlets are frequent in many of the beds and stigmaria with attached rootlets, showing that the deposits had taken place in rather shallow water, but not a single "strain" of coal was to be seen in any of them, and although the rootlets were so common, not a single other plant remain was got in connection with them. The rootlets run along the bedding, and also cut down through the strata.

There are some promising-looking nodules in some of the beds, but I found no plants in any of them.

The surfaces of some of the strata are crowded with the trails of animals, and there are also burrows going through them.

Plant-bearing Bed.

This bed has got a reddish tinge, part of it being exceedingly fine-grained and part slightly sandy. Many of the fossils in it are white, and beautifully preserved, showing the nervation and striæ. They looked very different from those got in the Black Coal Measure strata.

Upper Coal Measure Plants.*

Lepidodendron intermedium.
Lepidodendron cf. *fusiform.*
Lepidodendron dichotomum.
Lepidophyllum, sp.
Lepidostrobus variabilis.
Calamites ramosus.
Sigillaria discophora.
Sphenophyllum marginatum.
Annularia stellata.
Neuropteris impar.
Neuropteris Schenchzeri.
Neuropteris flexuoso.
Neuropteris rarinervis.
Neuropteris ovata.
Neuropteris (*Cyclopteroid pinule*).
Pecopteris Miltoni.
Pecopteris (*Cynthites group*).
Astrophylites.
Spiropteris.

*I am indebted to Dr. R. Kidston for the names of the plants mentioned in this paper.

Digitized by Google

Nothing further need be said on the rocks and fossils of this sinking till the Survey issue their report.

After my success at the above sinking, I made an examination of all the Red Coal Measure outcrops of strata surrounding the outlier of Permian rocks in the Ayr Valley, and although a large part of them may belong to the Upper Coal Measures, still no assemblage of fossils turned up like that got at the sinking, but the following notes on the "red beds" will be of interest in connection with the discovery of Upper Coal Measure plants in Ayrshire.

Ayr Water: Ballochmyle to Sorn.

The fine section on the right bank of the Ayr Water at Ballochmyle, just below Catrine, is distant 2½ miles N. of the sinking, and the strata are probably not far below those already noted there. Towards the top of the cliff there is a crumbling yellow sandstone, the rest of the strata being more or less reddish. Here occurs the spirorbis limestone, discovered by the late Mr. Binney, of Manchester, and considered to be on the horizon of the spirorbis limestones of the Manchester Coal Field. This limestone crops out on the Esk above Canonbie, where it is seen to be not far from the base of the Red Coal Measures, and in it last year I got remains of Megalichthys Hibberti, showing a great period of time for that fish—Calciferous to Upper Coal Measures.

From Ballochmyle to near Sorn occasional sections of Red Coal Measures are to be seen in the bed and along the banks of the Ayr Water, largely composed of sandstones, but few plants are to be obtained from them.

Auchenleck Burn.

This stream is distant 1¼ miles E.S.E. of the sinking, and from the Auchenleck-Cumnock road to the haughs of the Lugar it passes through a rocky gorge, cut mostly in sandstone beds of a red, dingy, or white appearance, some of them being pretty gritty; and light grey shales, with red ironstone nodules, occur sparingly. The only fossils I saw here were some plant débris.

Digitized by Google

Between the above road and the railway there are more sandstones and shales, with a 2-inch coal bed, of which I made a microscopic examination, but found no fossils in it—a white, waxy-looking substance in small particles is, however, not uncommon.

Nearer the Auchenleck to Muirkirk railway there is a fine-grained, grey limestone, 4 inches thick, with a lithographic fracture, of which I made a microscopic examination, but found no fossils. It has every appearance of having been a chemical precipitate.

The strata in the Auchenleck Burn are evidently below those noted for the sinking, and are probably towards the base of the Upper Coal Measures.

Cessnock Water.

The Cessnock Water, from near the mouth of Killoch Burn to near Fowler, shows a few interesting sections of the red beds, there being some notable mudstones, as near Craighead, where one of them is at least 40 feet thick. In another mudstone I saw red ironstone nodules streaked with yellow.

In the plantation, about 100 yards below the Craighead footbridge, there is a section with plant débris, calamites arenosus, &c., one of the bands resembling the blue band of the Water o' Ayr honestone, and has probably been indurated, but no sill is exposed.

Dalmore, Stair.

The Water o' Ayr whetstone, or polishing stone, if not actually in the Upper Coal Measures, cannot be far below their base. In a shale—altered by the heat of a dolerite sill—above the whetstone I obtained—

Calamocladus charæformis.
Lepidostrobus arenosus.
Dactylotheca plumosa.
Calamites undulatus.
Calamocladus equisetiformis.

In the purple band of the honestone itself I got—

Lepidodendron, sp.
Pecopteris Miltoni.

Digitized by Google

This band also contains lamellibranchs in a fair state of preservation. Little cavities in it have got calespar and green carbonate of copper, there being also soft, reddish nodules, which readily weather out on exposure to the air. Where the whetstone is mirled or spotted it appears to contain no fossils, the heat of the sill having probably dissipated them. Above the sill and below the hone bed there is a band of carbonite, originally a coal bed, and the heat of this sill has been great enough to convert part of the shale into lydian stone.

From Dalmore, going up the Ayr Water till the Permian lavas are reached, no exposures of rock are to be seen. This arises from two causes, the great thickness of the drift in this district and the softness of the beds composing this part of the Upper Coal Measures; in fact, we owe the Dalmore section to the strata at that place having been much hardened by the sill above mentioned.

Burn o' Need.

Amongst the first strata seen going up stream from the Ayr Water are sandstones tinged with red, then a massive bed of yellowish mudstone, with red veins passing irregularly through it.

A little further up in a side stream at a waterfall in a plantation I got skins of lamellibranchs in a reddish shale.

In the bed of the Burn o' Need, just below the Mauchline-Sorn road bridge, there is a fine-grained shale of a light purple colour crossing the stream, and containing the terminal twigs of lepidodendron, and a little further down—

Calamites Suckovi.
Annularia.
Stigmaria.

The strata below the above-mentioned bridge and for some distance above it are mostly reddish in colour, some of the beds being intensely red, and the ironstone nodules in the shales are also red. Even the cone-in-cone is red, of a small and very beautiful pattern, the upper cones having their apices pointing downwards, and the lower ones with the apices upwards.

Digitized by Google

The following little section shows the rapid change of colour that sometimes takes place in the red beds:—

Red Ironstone,	2 inches.
Dull-grey Shale,	15 ,,
Red Ironstone,	3 ,,
Creamy Sandstone,	3 ,,
Dull-grey Sandstone,	3 ,,

Grey sandstone with red nodules.

At one place on the Burn o' Need I saw part of a tree stem which may have been 2 feet in diameter, and a flattened plant 10 inches wide.

Some light-coloured shales have got intensely red nodules, as if the red matter, which usually goes to stain the shales, had got concentrated into irony lumps; and light-coloured beds of sandstone also contain intensely red nodules, to which similar remarks apply.

In a micaceous sandstone, probably not far from the base of the red beds, I got some fish remains.

Just about where the red rocks should terminate in going up stream I got a red ironstone nodule at the foot of a drift scaur with—

Productus.
Rhynchonella pleurodon.
Athyris ambigua.

and another red nodule contained bivalves.

The Red Coal Measures of the Burn o' Need have got one little coal bed ½ inch thick. It is brownish and soft, with layers of glance coal, vascular tissue, and aragonite.

Cleuch Burn.

The little Cleuch Burn has cut a deep ravine in the red beds before it joins the Ayr Water near Sorn Castle gates. The strata here are probably pretty near the base of the Red Coal Measures, as there is a coal bed in them, and I was informed by a man who had worked in the mine—driven in from the side of the glen—that it was about 2 feet thick. The rocks here are not intensely red, with the exception of the

Digitized by Google

ironstone nodules, and sandstones greatly prevail, some of them with white mica.

The only plants seen in the Cleuch Burn strata were—

Calamites.
Stigmaria.

In a heap of débris at a sinking between Sorn and Auchenleck I saw amongst some red material an 8-inch band of cone-in-cone, with the apices pointing both up and down. It was odd in being of a fine, white, silky appearance.

Burnock, or Black Water.

This stream joins the Lugar at Ochiltree, and red beds crop out here and there for a considerable distance up stream to beyond the Glasgow & South-Western Railway bridge. Plants are occasionally got, but none of them are sufficiently well preserved to be named specifically. Calamites and sigilaria occur, and some beds are crowded with roots, both in horizontal and vertical directions. I saw a bit of a tree stem 15 inches in diameter, and strong master-roots of stigmaria are occasionally observed.

The drift is well exposed at parts on the banks of the stream, and contains shells with both valves united. In it I detected several varieties of Coal Measure Limestone, one of them identical in structure to a band passed through in one of the red beds at a Dreghorn pit, and probably near the base of the Red Coal Measures. It is made up of greyish, reddish, and dark leafy layers, with short red veins crossing them, and appears to contain no fossils. Another leafy limestone was grey, stained with red, and contained plants and rootlets. The spirorbis limestone is also got in the drift here, and is crowded with specimens. I took 48 out of about a cubic inch of it. Fossils improve greatly on the limestone blocks containing them getting a little weathered.

The Burnock red beds are not remarkable for their depth of colour, and may be towards the base of the series.

Some of the grey sandstones have got the joints stained a red colour.

Digitized by Google

Burnockhill.

A sinking here passed through a small part of the red beds, and although I saw no fossils in them, the following were got in strata, perhaps not far below their base:—

Dactylotheca plumosa.
Neuropteris gigantea.
Neuropteris heterophyllia.
Pecopteris Miltoni.
Pecopteris Cyathea.
Pinularia capillacea.
Calamites Suckovi.
Annularia radiata.
Calamocladus charæformis.
Rootlets of Calamites.
Mariopteris muricata.
Sigillaria tesselata.
Cyclopteroid pinnle.

Ayr Water at Waterside.

On the left side of the Ayr some distance below Gadgirth in the bed of the stream there is the top part of a limestone bed of a greyish colour exposed with leaflets of Neuropteris gigantea. This bed is probably in the upper part of the Lower Coal Measures.

In this paper I have said nothing as to the probability of the Middle Coal Measures being got in Ayrshire, but this is a point which I have no doubt will be determined by the Geological surveyors so soon as the Auchenleck sinking passes the upper series.

Dr. R. Kidston has informed me that any fossil plants I have submitted to him cannot with certainty be relegated to the Middle Coal Measures.

Conclusion.

The Upper Coal Measures in Ayrshire are composed of quite a different class of strata as to their colour, and structure sometimes, from those that form the Lower Coal Measures, and the conditions of deposit, although somewhat similar in some respects, have been quite different in others.*

* The title "Lower Coal Measures" is here used for the lowest division of the Coal Measures proper, not for the coal-bearing rocks which occur in the Marine Limestone series, which in Scotland contains a number of thick coal beds, and is sometimes called the "Lower Coal Measures."

Digitized by Google

(1) Both series of strata have evidently been deposited in no great depth of water in a gradually and slowly sinking area.

(2) Repeated horizons crowded with the roots of plants are common to both.

(3) In the Lower Coal Measures we find bed after bed of coal about the root-bearing zones. In the Upper Coal Measures coal beds are all but absent from the root-bearing zones.

(4) In the Lower Coal Measures there is abundance of dark-coloured shales. In the Upper Coal Measures the shales are generally of a reddish tint, sometimes deep red in colour.

(5) In the Upper Coal Measures there are numerous beds of mudstone, or marl, of a reddish or yellowish colour. In the Lower Coal Measures there are no red or yellow marls.

(6) The sandstones of the Lower Coal Measures are grey or white, occasionally dark; those of the Upper Coal Measures are seldom white, often reddish, dingy purple, or yellow.

(7) The ironstones of the Lower Coal Measures are grey (carbonate of iron); those of the Upper Coal Measures are red (peroxide of iron), sometimes a little hydrated.

(8) The plants of the Lower Coal Measures are generally black and carbonaceous, and the tree stems have got a film of coal; those of the Upper Coal Measures are white, red, or purple, and the tree stems have got no coaly crust.

(9) The limestones of the Lower Coal Measures are light or dark grey in colour; those of the Upper Coal Measures always streaked or tinged more or less with red. In the Lower Coal Measures most of the limestones are of fresh-water origin, with one notable exception—the marine band. In the Upper Coal Measures (or at least the red beds) there is probably also a marine band, but the spirorbis limestone contains no fossils that can be said to be of marine origin; and the others are probably also fresh-water deposits.

From the above it is evident that there are three points to be considered in the differences that exist between the deposits of these two great formations.

(*a*) Why so much red colouring matter in the Upper and none in the Lower Coal Measures?

Digitized by Google

(*b*) Why so very little coal in the Upper Coal Measures?

(*c*) Why red and yellow marls and shales in the Upper Coal Measures and none in the Lower?

During the Upper Coal Measures period there was quite as much sediment forthcoming as there was during the deposition of the Lower Coal Measures, but at times rain evidently fell in torrents during the latter period, bringing down sediments which were often formed as mudstones; that is, marly beds without stratification.

During the Lower Coal Measures period the temperature was probably little higher than it is at the present day; during that of the Upper Coal Measures the temperature was very likely fiery-hot during summer, the sun's rays falling on large areas void of vegetation. The carbon of plants, after they ceased to live, got mostly dissipated in the form of gases, so that little vegetation accumulated and little coal was formed.

During the Lower Coal Measures period the rivers brought down abundance of plant débris, and their waters were constantly of a dark brown tint, derived from the maskings of peat bogs, this being the principal substance which gave the shales their dark colour.

During Upper Coal Measure times there appears to have been no peat mosses on the land and only, to a very small extent, in the delta swamps, and although there were trees of at least 2 feet in diameter, which occasionally got deposited in the sediments, little vegetation appears to have been carried by the rivers, the great bulk of both the land and swamp vegetation having been dissipated in the form of carbonic acid and other gases by the climatic conditions which prevailed for a very lengthened period.

The carbon which in the Lower Coal Measure times found its way in amongst the iron salts to form carbonate of iron, probably for the reasons given in last paragraph, did not do so during Upper Coal Measure times, so that the iron of that period occurs as peroxide, and although there is so much red colour in the Upper Coal Measures strata, still there is probably no more iron in this formation than there is in the Lower Coal Measures, as it takes exceedingly little red oxide to stain a rock.

Digitized by Google

The red colour of this great formation (the Upper Coal Measures) is evidently native to the beds—not derived from another formation. As we have seen, this stain has sometimes got washed out of the beds, more or less, and deposited in the joints, but this may be quite a recent occurrence. We have also seen that where red ironstone bands and nodules occur in shales and sandstones the red oxide has been withdrawn from these rocks to form the ironstones, leaving the former comparatively light in colour, this having evidently been done before the beds consolidated, and is good proof that the red colour is native to the strata.

But for its plants, which have a general resemblance to those of the rest of the Carboniferous system—some of the species being the same as those got lower down—the Upper series do not deserve the name of Coal Measures—it contains little coal, and has not been often measured.

Digitized by Google

No. XIX.—Notes on a Dolerite showing Ocellar Structure, from Craigie Hill, Ayrshire. By Peter Macnair, F.R.S.E., F.G.S.

[Read 9th April, 1908.]

In my paper on the intrusive dolerites found in the neighbourhood of Glasgow which I contributed to the Society last year, I drew attention to a peculiar structure which I had noticed in a thin section from the Craigie Hill dolerite, Ayrshire, and which I described as follows:—Throughout the rock occur a large number of oval or circular-shaped aggregations of crystals and glass, the largest of which do not exceed 50 mm. in diameter. These aggregations usually consist of a central nucleus of augite, lath-shaped felspar, and brown glass. I have since examined the specimens more carefully, and I am now in a position to give a more detailed account of this interesting structure, as well as other phenomena not referred to in my last paper.

The Craigie Hill intrusion occurs about 4 miles to the south of Kilmarnock, while another intrusion of the same character occurs at Dundonald, about 1 mile to the west of Craigie Hill. Both of these intrusions present all the usual characteristics of these dolerite sills. It has been shown in the paper referred to that along the line of contact with the sedimentary rocks these sills have cooled more rapidly than in their more central parts, and, as a result of this, they exhibit a much more finely crystalline structure towards their edges than they do in the centre. In some rare cases, as at the Fossil Grove, Whiteinch, the sill has sent off small veinlets and threads, which have cooled so rapidly that they have passed into a glassy condition, and exhibit a well-developed spherulitic structure.

At a distance of about 6 feet from the chilled edge the Craigie Hill rock presents all the appearance of an ordinary dolerite, both in hand specimens and when seen under the microscope. When viewed under the latter condition, the

Digitized by Google

rock is seen to be a holocrystalline aggregate of augite, plagioclase, and olivine, with magnetite, apatite, and pyrites as accessory constituents. The bulk of the rock consists of augite and plagioclase. The former mineral occurs in well-shaped crystals showing the following forms:—110, 100, 010, and 111. Twinning upon the orthopinacoid is not uncommon, and in some instances this has taken place several times. The augite is usually brown, or of a pale yellowish colour, but in some cases it presents the pale purplish tinge often to be seen in the intrusive dolerites of the West of Scotland. One crystal shows a core of pale yellow colour, surrounded by a zone of a deep purplish tinge. This section his evidently been cut out of the 100 : 001 zone, as it shows the emergence of an optic axis, and is bounded by well-defined prisms and pinacoid faces. The internal core of a pale brown colour is sharply defined from the outside rim of purplish colour, the boundary line between the two colours running parallel with the faces. Many of the crystals also show the peculiar joining known as hour-glass structure. The cleavage is usually well marked, and is shown in sections at right angles to the *c* axis by a series of interrupted lines running parallel with the prism faces.

Plagioclase felspar occurs in crystals which have been elongated parallel to the *a* axis. It exhibits the characteristic polysynthetic twinning known as the albite law. Pericline and Carlsbad twinning also occur.

Olivine is abundant in all the sections which I have examined. It sometimes exhibits crystallographic contours, but usually presents irregular indented outlines, due to corrosion. It may be observed in all stages of alteration from the perfectly fresh, glassy condition to crystals which have passed almost entirely into serpentine.

Hornblende is fairly abundant in this rock, and has all the appearance of being an original constituent. It occurs in well-defined crystals which show the usual habit of this mineral. I have also observed traces of secondary hornblende pseudomorphous after augite; as I have already discussed this mode of occurrence of hornblende in my former paper, no further reference is needed here.

The accessory minerals are apatite, magnetite, and pyrites.

Digitized by Google

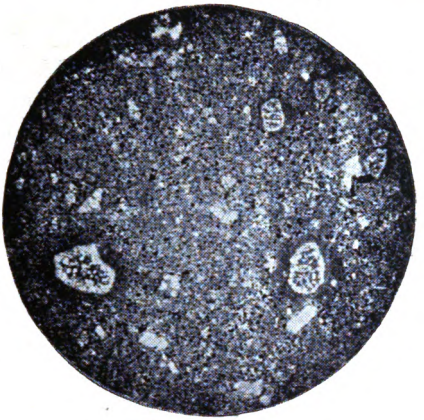


Fig. 1, ×25.

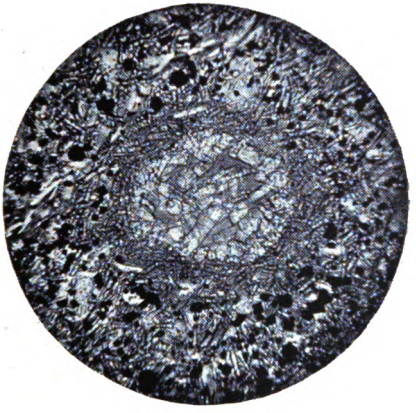


Fig. 2, ×100.

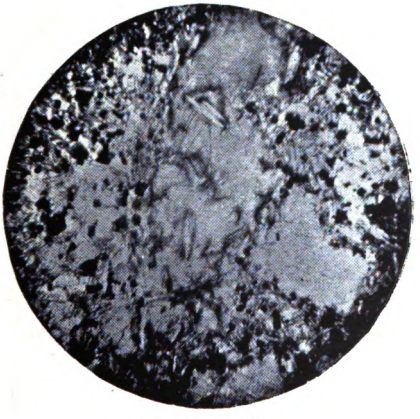


Fig 3, ×100.

Ocellar Dolerite from Craigie Hill, Ayrshire.

Digitized by Google

Digitized by Google

Apatite occurs in the usual habit of long, slender, hexagonal needles, which are often seen to penetrate the other constituents of the rock. Magnetite and iron pyrites are abundant, and occur both in grains and in well-defined crystals.

In my former paper I pointed out the existence of what appears to be original analcite in this rock, the presence of which allies it with the teschenite of Hohenegger, which occurs as intrusions amongst the Cretaceous rocks of Silesia and Moravia. The analcite plays the rôle of groundmass, and is seen to enclose all the other constituents of the rock. In an area of analcite which measures about a square millimetre, perfectly idiomorphic crystals of plagioclase, hornblende, and apatite are seen to occur.

Passing now to a description of the dolerite taken from the chilled edge, it may be noticed, in the first place, that, structurally, the rock presents a striking contrast to the normal dolerite just described. Instead of being holocrystalline, it is distinctly hemicrystalline even to the naked eye, and, when examined under the microscope, it is seen to contain a large quantity of brownish coloured glass which is perfectly isotropic. The glass is fairly evenly distributed through the rock, as is shown when it is viewed under crossed nicols. Here and there strings and patches of the glass can be observed, and to these I shall presently refer in more detail. Through the hyaline groundmass there has been developed augite with small lath-shaped plagioclase. The plagioclase has crystallised out first, and the structure may be described as minutely ophitic. Associated with the augite and plagioclase is a large quantity of magnetite. Phenocrysts of olivine, augite, and plagioclase are distributed through this hemicrystalline groundmass.

Besides the phenocrysts just referred to, there occur numerous ocelli, which vary in size from ·25 up to ·5 mm. in diameter. These ocelli also vary considerably in shape; some of them are nearly spherical, while others are oval. In other cases they appear to have no very definite outline, and simply appear as irregularly bounded patches. Like the phenocrysts, they are set in the groundmass of augite, felspar, and glass.

The phenocrysts of olivine, augite, and plagioclase evidently belong to an earlier generation than the crystals which

Digitized by Google

constitute the groundmass. They usually exhibit traces of having originally assumed well-marked idiomorphic outlines, though they have suffered much from subsequent corrosion.

The ocelli are composed of a series of concentric shells, the innermost of which, or the core, consists of augite and brown glass, with laths of felspar. Surrounding this is a layer of augite without glass. This is succeeded by a zone of tangentially arranged felspars with glass, but without magnetite. The ocelli and phenocrysts of plagioclase, augite, and olivine are set in the hemicrystalline groundmass of brown glass, augite, plagioclase, and magnetite. From the description it will be seen that all the mineral constituents of the rock enter into the composition of the ocelli with the exception of the magnetite. When viewed under a low magnification, as in Fig. 1, Plate XII., the whole structure of the rock can be distinctly seen. Two of the largest ocelli are seen on the right and left of the lower part of the section, while in the upper right-hand corner several of the smaller ocelli can be seen. In this figure there is also shown numerous phenocrysts of olivine, plagioclase, and augite. Figure 2 shows one of the ocelli under a much higher magnification, and exhibits their structure in more detail. In it there is shown the usual core of augite, plagioclase, and glass, succeeded by the tangentially arranged felspars and enclosed in the hemicrystalline groundmass. As a general rule, the succession of zones just described seems to hold good, but in some cases a slight departure from this rule may be observed. An interesting modification is exhibited in one of the ocelli where the nucleus is entirely crystalline, no glass being present, whilst the tangential felspars are set in an exceptionally large quantity of glassy material.

I have already referred to the existence of strings and patches of brown glass which are scattered through the rock. Some of these are of considerable size, and may measure 4 to 6 mm. in length by 1 mm. in breadth. One of these patches of glass is shown in Fig. 3. Skeleton crystals of plagioclase are numerous in the glassy groundmass, and these are seen to be surrounded by minute microlites, often aggregated into feathery forms in much the same manner as can be seen in

Digitized by Google

the pitchstone of Arran. Some of the felspar prisms exhibit bifid ends. Perhaps the most noteworthy feature in this rock is the remarkably fresh appearance of the glass, as it exhibits very little signs of devitrification.

In conclusion, a brief account may be given of what I believe to have been the origin of the structures just described. It appears to me that the ocelli and phenocrysts have been the first to crystallise, and that they must have been formed along the line of contact when, as yet, the main mass of the rock had not consolidated. The formation of the ocelli probably slightly preceded that of the phenocrysts. The nucleus was the first to form, and it has followed the normal order of crystallisation, the augite being allotriomorphic towards the plagioclase. This is well shown in Fig. 2. Around this kernel there was then formed a zone composed almost entirely of augite without glass. This was succeeded by the tangentially arranged felspars; and, lastly, the groundmass crystallised out, enclosing both the phenocrysts and ocelli of the earlier generation. A gradual passage can be traced from this hemicrystalline chilled edge with the peculiar structures just described into the holocrystalline dolerite. This passage is characterised by a slow decrease in glassy material, and by an increase in size and perfection of development of the different mineral constituents of the rock.

Digitized by Google

No. XX.—A Puddle-trench Section at North Third, near Bannockburn, with Notes on the Geology of the Surrounding District.

By N. Martin, B.Sc., C.E., and G. W. Tyrrell, A.R.C.Sc., Assistant in Geological Department, Glasgow University.

[Read 14th May, 1908.]

I. Introduction.

The section described in this paper has been exposed in the course of construction of a reservoir for the Grangemouth Town Council, near North Third farm steading, 4½ miles S.W. of Stirling, and about 3 miles W. of Bannockburn. The puddle trench has been excavated in an E.-W. direction along the centre line of a proposed embankment, which, when completed, will dam back the upper waters of the Bannock Burn. The *raison d'être* of a puddle trench may readily be grasped by a glance at Fig. 1. Although the earthwork embankment built across the valley might itself be impervious to water, the pressure due to the water in the reservoir would force the water along the previous subsoil and strata underlying the embankment. To prevent this leakage, which would not only be a source of waste but a positive menace to the stability of the embankment, a trench is sunk along the centre-line of the proposed embankment until a solid, impermeable stratum is reached, or at least to a depth at which no serious leakage from the reservoir is expected. The trench is then packed with "puddled clay," forming an impermeable wall through the opener strata under the embankment. The puddled clay is continued right up through the heart of the embankment, rendering that watertight also. The figure below shows the method of construction.

The North Third puddle trench is about 340 yards long, with a width of about 15 feet, and a maximum depth of about 100 feet. A plan of the trench is shown on Plate XIV. It is excavated up to the present entirely in the upper part of the Calciferous Sandstone volcanic series. The extreme eastern

Digitized by Google

end of the trench cuts through the last lava flow before the oncoming of the overlying cement stones. Although covering a wide extent of country, the volcanic series is the least conspicuous of the igneous rocks to the S.W. of Stirling. It forms a barren upland of rough hill pasture, dotted all over with numerous small lava escarpments, and overlooked by the bold mural escarpment of the great Stirling sill.

Not much has been written concerning the geology of this district. The three chief references are the Geological Survey Memoir of Sheet 31 (1879),* two papers on the geology of the Stirling district by H. Monckton,† and, of course, the area is included in Sir A. Geikie's monumental work on "The Ancient

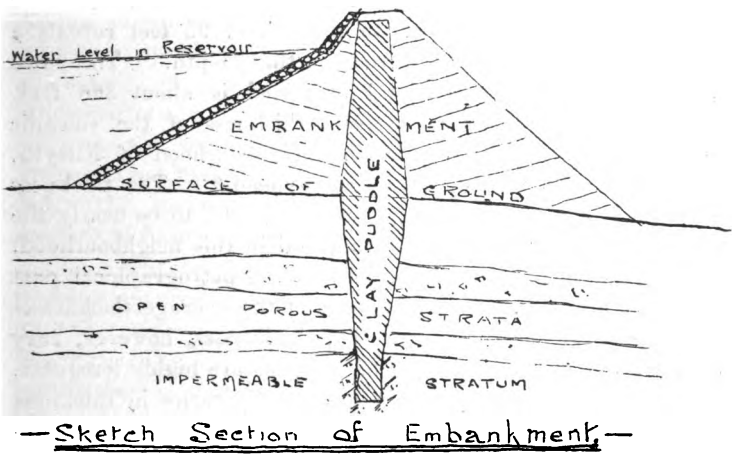


Fig. 1.

Volcanoes of Great Britain" (1897), although few special references are made.

The fieldwork for this paper has been done conjointly by the authors. Mr. Martin is mainly responsible for the descriptive and stratigraphical part of the paper, Mr. Tyrrell for the petrographical. The section in the trench is first described,

* The puddle trench falls in Sh. 39, to which no memoir is attached; but the memoir on Sh. 31 describes the same formations a little to the south of this area.

† Monckton. *Proc. Geol. Assoc.*, vol. xii. (1891-2), p. 242.
,, *Q.J.G.S.* (1895), li. pp. 480-491.

Digitized by Google

then the geology of the surrounding district, of which the two main features are the Sauchie cliff and the fine section of the Carboniferous Limestone series exposed in the gorge of the Bannock Burn. The history of the river system of the district is dealt with briefly, and the paper closes with a petrological investigation of the volcanic rocks exposed in the trench.

II. The Section in the Puddle Trench.

The rocks exposed in the puddle trench are a series of lavas and tuffs dipping eastward at an angle of 10 degs. These form hard and soft beds alternating regularly, and the latter being known to the workmen as "cutters." A diamond drill boring in the bottom of the trench to a depth of 95 feet reveals a continuation of the same series to that depth. The total thickness of volcanic material examined is about 366 feet. Sir A. Geikie estimates the total thickness of the volcanic series at about 1000 feet in the neighbourhood of Kilsyth, thinning out to nothing at Causewayhead.* The thickness obtained in the trench ought, on this estimate, to be nearly the total thickness of the volcanic material in this neighbourhood.

The rocks exposed are described in the petrographical part of this paper, in which a statement of the average thicknesses of the nineteen beds is given. The thicknesses, however, vary considerably, and the surfaces of the flows are highly irregular. For instance, the lava flow designated (E) varies in thickness from 15 to 28 feet, (C) from 34 to 60 feet, and (O) from 80 to 110 feet.† The latter is the greatest thickness attained by any one flow. The tuffs vary in thickness in like manner, but are inferior in this respect to the lavas, except towards the top of the series.

Some of the "cutters" are undoubtedly merely slaggy portions of lava flows. This fact explains the interleaving of one of the flows (G) by a tongue-like projection of "cutter," which gradually thickens until it joins the underlying slag (F). The interpolated bed is merely a highly vesicular or slaggy portion of (G), which weathers as a soft bed.

* "Ancient Volcanoes of Great Britain" (1897), vol i., p. 393.

† See table on p. 250.

Digitized by Google

Intercalated between I and H, also in P and R, are thin beds of fine red, muddy tuff ranging up to 2 feet in thickness. This rock is soft and decomposed where the trench water has been flowing over it, but is sometimes hard, splintery, and ringing to the hammer when dry and unweathered. This material probably indicates slow deposition of very fine volcanic dust and sedimentary material in temporary accumulations of water on the irregular surfaces of the lava flows. The abundant iron oxides of the decomposing lavas were also washed down into these temporary lagoons, giving the deposited material its bright red colour.

In blasting, the hard beds, especially the thick flow O, have broken away along remarkable planes of division known to the workmen as "backs." These consist of large, smooth, curved surfaces, of any size from 1 to 20 feet in diameter. A fine example is shown in Plate XIII., Fig. 2. These surfaces are sometimes crowded together, forming a series of concentric spherical shells of rock, from which occasionally large curved plates of rock about ½ inch thick may be broken off. The smooth surfaces of the "backs" are sometimes crossed horizontally by a few blunt, rounded ridges.

These surfaces are not developed by weathering, but only become apparent on fracture. The authors believe they are due to a series of concentric surfaces of weak cohesion developed during cooling, which, while they cannot be detected in the unweathered, unbroken rock, control its fracture when broken by such a violent means as blasting. The structure may perhaps be considered as perlitic structure on a gigantic scale. These "backs" are characteristic of lavas or intrusive rocks which have reached nearly to the surface, and which have consequently been subjected to rapid cooling. These varieties of whinstone are known to the quarrymen as "clinker" rocks, as opposed to the varieties due to the deeper-seated intrusions, which are generally more regularly columnar in structure and weather into spheroidal masses, and which are distinguished by the quarrymen as "liver" rocks.

A vertical zone of crushed and brecciated rock 42 feet wide crosses the west end of the trench in a N. and S. direction. There does not seem, however, to have been any vertical disloca-

Digitized by Google

tion of the adjacent beds. The brecciation may therefore be due to a lateral wrench. The brecciated rock has been eroded to a depth of 10 feet, and the hollow thus formed filled with boulder clay.

III. Geology of the Surrounding District.

Overlying the volcanic series to the E. of the trench is a thin band of cement stones, followed by the lower beds of the Carboniferous Limestone series, into which is intruded a great sill, or, rather, flat laccolite, of diabase. This sill is found over a N.-S. distance of about 10 miles, and its escarpment forms a magnificent range of vertical cliff stretching with few breaks from the Wallace Monument and Stirling Castle on the north to Myot Hill on the south. At Sauchie the sill is just above the Hurlet Limestone, but to the S. its base rises higher and higher in the series. At the same time the sill becomes thinner. Just opposite the trench is a fine cliff section showing a large mass of sandstones and shales caught up and enveloped by the igneous rock.* The sill is broken by three large E.-W. faults into three main blocks, which have the appearance, owing to denudation, of having been displaced relatively to each other. The rock of the sill is a quartz diabase, or micropegmatitic diabase, of the whin sill type.†

The most complete section, however, between the volcanic series and the Hurlet Limestone occurs in the Bannock Burn about half a mile N. of the trench. Above this point the stream meanders in an alluvial plain, which was probably the site of a glacial lake. At this point, however, begins an abrupt descent, and the stream has cut a deep gorge through the volcanic series, cement stones, and Carboniferous Limestone series, until the northernmost E.-W. fault is reached, when the river makes an abrupt turn to the east, and flows along the fault line.

Following the stream from the trench northwards, the boundary of the hard lavas is fairly well marked by the

*H. W. Monckton. *Proc. Geol. Assoc.*, vol. xii. (1891-2) p. 245.
†H. W. Monckton. *Q.J.G.S.* (1895), li., pp. 480-491.

Digitized by Google

termination of a deep, vertical-sided, rocky gorge. This is followed by a steep-sided, grassy valley, in which sections are not infrequent in the banks of the stream. The last important lava flow is overlaid by coarse, variegated tuff, of which there is a visible thickness of 5 feet in a small runnel on the E. side of the burn. Seventy yards further down stream is an exposure of stratified blue and red mottled tuff, containing some large ejected blocks of vesicular lava. The tuff is very calcareous in places, and towards the top is interstratified with thin, impersistent bands of brick-red cement stones. This is followed by a bed of decomposed vesicular lava about 6 feet thick, then by a bed of blue tuff with large decomposed felspars, evidently due to the explosive disintegration of a porphyritic magma. Overlying this are red and greyish-green tuffs containing much sedimentary material. The top beds are brick-red cement shales, still containing, however, some volcanic material. A further exposure of higher beds shows typical cement stones with an interstratified band, 6 to 12 inches thick, of coarse tuff or agglomerate, containing pebbles up to 1½ inches in diameter. The dip is about 10 degs. to the N.

The boundary between the cement stones and the Carboniferous Limestone series is not actually seen, but there is only a small break between the last exposure of cement stones and the first limestone. The above account of the section shows that the cement stone group in this area is composed mainly of volcanic material, and proves that volcanic activity did not die out until just before the beginning of the Carboniferous Limestone epoch.

The first exposure of the Carboniferous Limestone series is a bed of hard, black, fossiliferous limestone, forming a small fall in the stream. The section at the waterfall is as follows:—

	Feet.	Inches.
Hard black fossiliferous limestone,	1	6
Fossiliferous calcareous shales,	1	0
Hard limestone,	0	3
Black shales,	0	6 visible.

Exactly the same succession occurs in the bank 3 feet above the fall, but these beds are not continuous with those forming the fall. Below the waterfall is another ledge of limestone with part of the same succession visible, and overlain by black

Digitized by Google

shales. These appearances are best explained by assuming two small step faults at the waterfall, each of about 4 feet throw.

This limestone is some distance below the Hurlet seam. It is succeeded by at least 20 feet of black shale. Then follows in ascending order—

	Feet.	Inches.
Calcareous shale, with spherical limestone concretions up to 18 inches diameter,	6	0
Black shale with thin rib of limestone,	3	0
Hard fossiliferous limestone,	1	6
Black shale,	thickness undetermined.	

The dip is uniformly about 10 degs. N.

Further down stream occurs a finely-exposed syncline bringing on the first limestone again. The Hurlet Limestone is high up in the bank on both sides, and has been extensively worked.

We had not the opportunity of thoroughly examining this fine section, and of collecting its fossils. It is well worth the combined attention of stratigrapher and palæontologist.

IV. History of the River System.

The drainage of the district affords a good example of the influence of a bar of hard rock athwart the main direction of the streams. The consequent streams in this part of Scotland have a general N.W.-S.E. direction. In this particular district the relief has been developed mainly by a series of subsequent streams running nearly due E. and W., and discharging into the Forth below Stirling. The upper Forth itself above Stirling, the Bannock Burn, Pow Burn, and the Carron River are examples of these. Athwart all these is the great bar of the Stirling sill, running 10 miles from N. to S. The Forth itself, by reason of its size, volume, and erosive power, has been able to cut its channel down through the hard bar, concomitantly with the sculpturing of the escarpment on either side. It is clear that the rock on which the Wallace Monument stands and the Stirling Castle rock were once continuous at the surface, and even now are probably connected underground. At the present time the area between the severed portions of the escarpment, 1½ miles wide, is occupied by a large meander of the river. The original Bannock Burn

Digitized by Google

has been enabled to survive by the fortunate chance of its having found the most northerly E. and W. fault. Then lateral tributaries, cutting back rapidly along the comparatively soft rocks on either side of the sill, have captured the headwaters of the Pow Burn, of which the upper Bannock Burn, the Sauchie, and the Auchenbowie Burns are the remnants. The southern headwater of the Pow Burn, now represented by a part of the Auchenbowie Burn, has been beheaded twice—first by the Bannock Burn cutting southward along the western edge of the sill, and then by a tributary of the Carron working northward along the eastern edge. The northern headwater of the Pow Burn has left a fine windgap in the Sauchie cliff opposite North Third.

It seems probable also that during the glacial period the upper waters of the Bannock Burn were dammed back by a great mass of ice blocking up the narrow gap at Wallstale between the Gillie's and the Sauchie cliff, forming a lake between the Sauchie cliff and the volcanic hills to the west. The reservoir now building will occupy the site of this vanished lake. The processes of erosion were suspended in the upper Bannock Burn during this period, but they were probably still active in the lower reaches. The upper Bannock Burn, therefore, presents some of the characteristics of a hanging valley, connected with the alluvial flats below by a deep, post-glacial gorge.

The authors gratefully acknowledge the facilities for visiting the trench kindly given by Messrs. Warren & Stuart, Glasgow, the engineers for the works.

Petrography of the Volcanic Series at North Third Puddle Trench. By G. W. Tyrrell, A.R.C.Sc.

The rocks occurring in the puddle trench consist of twenty-two beds, of hard and soft rock alternately, the latter termed "cutters" by the workmen. The greater number of the beds are visible in the open cutting, and the remainder were obtained by means of chisel borings in the bottom of the trench. On closer examination some of the soft beds or "cutters" turn out to be merely the slaggy upper or

Digitized by Google

lower surfaces of the adjacent lava flows, but the remaining soft beds are shown to be true tuffs, both by their stratified appearance and by microscopical examination.

When the slags are included with the lavas, of which they are a part, the number of beds is reduced to nineteen. The twenty-two apparently separate beds were lettered from A to U in ascending order before the true nature of some of the softer rocks had been ascertained. In order to avoid confusion, however, the original lettering has not been altered, but the indivisible nature of beds containing both hard lava and slag has been indicated by conjoining the letters assigned to the lava and slag respectively.

The delimitation of the various beds has been a matter of some difficulty, on account of the nature of the exposure and the inaccessibility of parts of the cutting. The rocks are very wet and frequently covered with a red slime consisting mainly of hæmatite leached out of the volcanic rock itself.* The continual trickling of water down the sides of the trench has washed out portions of the softer rocks, so that the junctions between adjacent beds are often obscured by layers of mud.

The hard lavas are easily recognised by their massive appearance and by their peculiar spherical jointing. The slags and tuffs are very much alike in hand specimens, but are fairly easily distinguished, under favourable circumstances, in the cutting—the former by their gradual passage into the hard lavas and lack of stratification, the latter by a distinct stratification and the presence of lapilli and small blocks of lava.

Macroscopic Characters.—The lavas may at once be divided into a lower non-porphyritic and an upper porphyritic group; but, following the upper group, there are two thin, non-porphyritic flows, which are the last of the series in this district, and which show distinct characteristics of their own.

Bed A, the lowermost lava obtained in the bores, is a compact, greyish, non-porphyritic, somewhat porous rock, whose specific gravity, as determined by Walker's steelyard, is 2·57. Although this figure is open to suspicion, on account of the

* The workmen informed us that painful wounds were caused by this substance if allowed to get into cuts or abrasions.

Digitized by Google

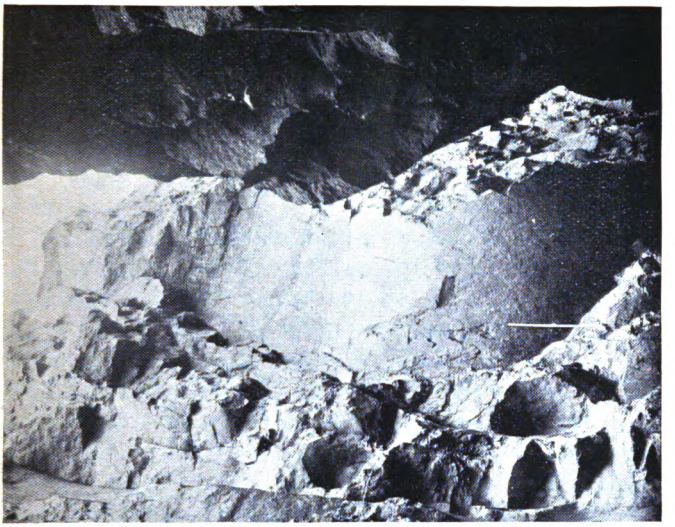


Fig. 2.

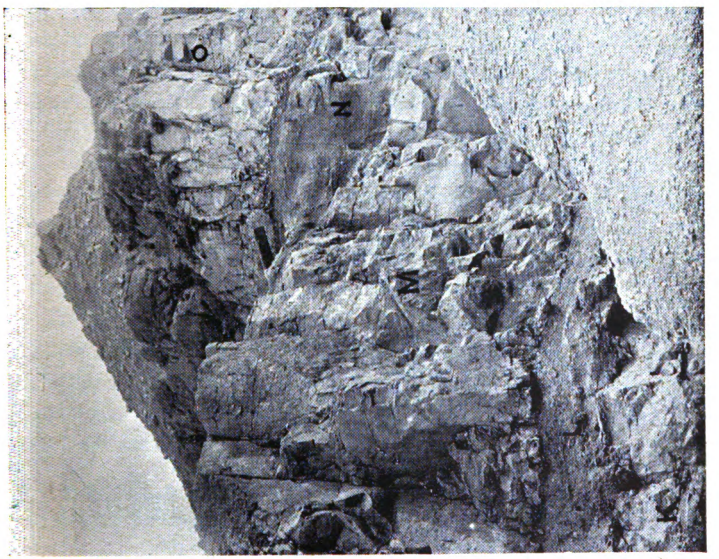


Fig. 1.

Digitized by Google

Digitized by Google

slightly porous nature of the rock, it indicates a lava of the nature of a trachyte. C and E* are dark, hard, compact, non-porphyritic rocks, of specific gravity 2·70 and 2·85 respectively. C has a conchoidal fracture, and frequently shows small vesicles elongated in the direction of flow. Both C and E are stained and veined with hæmatite. E shows a transition to the upper group in containing an occasional porphyritic felspar.

The upper group, consisting of Beds G, I, K, M, O, and Q are all highly porphyritic and amygdaloidal. The phenocrysts are invariably of plagioclase, set in a compact, dark-grey base. The vesicles are filled with calcite, chalcedony, quartz, zeolites, "green-earth," and sometimes with hæmatite and wad. The specific gravity of these rocks varies from 2·79 in I to 2·69 in K, the other four rocks having intermediate values. These figures cannot be relied on, on account of the numerous amygdules. In I, the heaviest of the group, the felspar phenocrysts and the amygdules are least abundant. In all cases the groundmass is similar to that of the rocks C and E, so that the presence of numerous felspar phenocrysts may perhaps be taken to indicate a slight decrease of basicity from the lower to the upper group.

The two last flows, S and U, are of entirely different character, and indicate a return to the type of the lower group. They consist of a very fine-grained, greyish-green rock, whose fracture shows a resinous lustre, and which weathers with a bluish crust. There is occasionally a small porphyritic felspar. It presents a characteristic appearance in the field, close horizontal and vertical joints having broken the rock into small tabular pieces. On account of this mode of jointing and of its susceptibility to extreme weathering, it is very difficult to get even a comparatively fresh specimen.

The slags are soft, highly vesicular rocks, the vesicles of which are usually filled with amygdaloidal secondary minerals similar to those of the lavas above described. Sometimes, however, the vesicles are empty, and the rock is then porous and cellular.

* The intermediate beds, B, D, &c., are tuffs and slags, which are hereafter described.

Digitized by Google

The tuffs are soft, crumbling, purple, red or green-tinted rocks, usually fine textured and well stratified. True lapilli are sometimes seen, and also occasional small ejected blocks of compact lava. Hand specimens are naturally very difficult to get in the open exposure, but specimens from the bores are hard enough to be sliced.

Microscopic Characters.—The microscopical examination of the lavas shows that they are rocks of a highly felspathic nature, passing on the one hand into rocks of a trachytic type, and on the other to relatively acid felspathic basalts. It will be seen later that they closely resemble the mugearites of Skye and Midlothian. The following table gives the succession of the various beds, with their average thicknesses and, in some cases, their specific gravity:—

Bed.	Thickness.	Name.
U,	12 feet,	Trachytic Mugearite (2·62).*
T,	4 ,,	Tuff.
S,	10 ,,	Trachytic Mugearite (2·56).
R,	17 ,,	Tuff.
Q,	10 ,,	Mugearite, porphyritic.
P,	16 ,,	Tuff.
O,	110 ,,	Mugearite, porphyritic (2·78).
N,	4 ,,	Tuff.
M,	11 ,,	Mugearite, porphyritic.
L,	4 ,,	Tuff.
K,	21 ,,	Mugearite, porphyritic (2·69).
J,	6 ,,	Tuff.
I,	19 ,,	Mugearite, porphyritic (2·79).
H,	6 ,,	Slag.
G,	15 ,,	Mugearite, porphyritic (2·74).
F,	3 ,,	Slag.
E,	19 ,,	Mugearite (2·85).
D,	15 ,,	Slag.
C,	29 ,,	Mugearite (2·70).
B,	8 ,,	Coarse Tuff.
A,	27+,,	Trachytic Mugearite (2·57).
Total,	366 feet.	

The flows A, C, and E differ so little from one another materially that it is convenient to describe them together. Under the microscope they are seen to consist essentially of a closely-packed aggregate of small laths of felspar, which show a decided fluxional arrangement, having their longer axes parallel to one another at any given point. The interspaces between the felspars are filled with abundant ragged

* The figures within brackets indicate the specific gravity of the rock.

Digitized by Google

granules of magnetite and reddish flakes of hæmatite. Here and there a minute granule occurs which may perhaps be identified as a pyroxene, but the bulk of the ferro-magnesian element occurs as vague green chloritic material interspersed between the felspars. The proportion of ferro-magnesian minerals is in any case very small, compared to that of the felspar. It increases as the series is passed up from A to E, but even the latter rock is still highly felspathic. Many of the felspar laths are untwinned and give straight extinction. These are probably orthoclase, but the remainder show lamellar twinning, and give an extinction angle of about 5 degs. These are, therefore, to be identified as oligoclase. The proportion of oligoclase is greatest in E and least in A. In C there are a few small green, rectangular pseudomorphs, probably after augite or hypersthene. In E a few calcite pseudomorphs occur, which have the characteristic hexagonal shape of olivine. The iron ore in this rock is more abundant than in A and C, and a conspicuous feature is the occurrence of knots of closely-aggregated, clear, red flakes of hæmatite surrounding a ragged nucleus of magnetite. The hæmatite is obviously secondary, as it surrounds, replaces, and penetrates the felspars by their cleavage and other cracks.

The high proportion of the felspathic constituent allies these rocks with the trachytes. They differ from them, however, in the large content of iron oxides. In the relatively acid nature of the felspathic groundmass, the insignificance of the ferro-magnesian minerals, the abundance of magnetite, and the probable occurrence of orthoclase and olivine, they present considerable affinities with the mugearites of Harker.* Where, as in A, the potash and lime-soda felspars are evenly balanced, the rock may properly be termed trachytic mugearites. Where, as in C, the lime-soda felspar predominates, and the ferro-magnesian element, though still small, is in greater proportion, the rock resembles more closely the typical mugearite of Druim-na-Criche. In E, where the more basic character is indicated by the specific gravity (2·85), by a higher content of iron oxides, and by the occurrence of a few pseudomorphs after olivine, the rock approximates to the

* Harker. "Tert. Ign. Rocks of Skye" (1904), pp. 265-267.

Digitized by Google

basic mugearite from Huisgill, near Talisker. The three rocks, however, form a quite continuous series of increasing basicity from A to E.

The porphyritic group, consisting of Beds G, I, K, M, O, and Q, is of a homogeneous character, and may be described as a whole. The groundmass is similar to that of the compact rocks described above—closely-packed laths of felspar, with abundant magnetite and hæmatite, but with little or no ferromagnesian element, except in O. There is occasionally a little irresolvable substance in the groundmass, but no isotropic matter. The phenocrysts are entirely of plagioclase, and are usually perfectly idiomorphic. They are much altered and full of red flakes of hæmatite, which has penetrated the crystals through the channels afforded by the cleavage and other cracks. They are frequently zoned with rod-like inclusions of the groundmass arranged parallel to the boundaries of the crystals. Both carlsbad and albite twinning is shown. The maximum extinction angle obtainable for the albite lamellæ in sections giving symmetrical extinction varies from 28 degs., indicating a medium labradorite, in G and K, to 17 degs., indicating an andesine-labradorite, in I and O.

In G occur a few microporphyritic pseudomorphs in red serpentine after olivine. In K occurs the only phenocryst of augite discovered in the whole series of slides. It is small and much decomposed. The felspar phenocrysts in this rock have sometimes served as nuclei for aggregations of iron oxides. In K and O are several large crystals of a black, opaque mineral, which, from its form, appears to belong to the hexagonal system. In reflected light these are of an iron-grey tint, and are seen to be striated with black lines crossing in two directions at an angle of about 72 degs. This mineral is most probably a titaniferous iron ore of the ilmenite group.

The vesicles in these rocks are filled with calcite, "green-earth," various zeolites, chalcedonic silica, and sometimes also hæmatite and wad. Frequently there is more than one mineral in the vesicle. The most common appearance is of a thin peripheral shell of hæmatite, the interior being filled with calcite, quartz, or "green-earth."

The last two lavas, S and U, are composed of a mesh of

Digitized by Google

Digitized by Google

Digitized by Google

minute laths of felspar, with small intersertal granules of a bright yellow mineral, and ragged specks of black iron ores. The better-preserved felspars are untwinned, and give straight extinction in the greater number of cases. These are probably orthoclase. A few, however, show lamellar twinning, and a maximum extinction angle of 5 degs., and are thus oligoclase. The bright yellow intersertal mineral is structureless in ordinary light, but in polarized light a radial structure is revealed by a series of dark extinction "brushes." It is undoubtedly a form of serpentine. It occurs occasionally as small, roughly rectangular, and hexagonal pseudomorphs, which certainly suggest olivine. There is a little colourless isotropic material in the groundmass. The specific gravities of these rocks are 2·56 and 2·62 respectively. They are, therefore, as indicated by their microscopic characters, slightly more acid than C and E. They resemble A very closely, and are thus to be regarded as transition forms between mugearite and trachyte. The fresh rock would probably contain olivine. The slags in thin section, as, *e.g.*, H, differ from the lavas only in being more highly altered and vesicular.

The tuffs are mugearite tuffs, that is to say, they consist of small lapilli of the compact type of lava, in a base of comminuted felspars, the whole thoroughly impregnated with iron oxides. They are composed almost entirely of volcanic material. Only in the red muddy tuffs before mentioned is there any considerable admixture of sedimentary material.

As before mentioned, these rocks in all probability belong to the mugearites of Harker. They are essentially felspar-magnetite rocks, with comparatively acid felspars and a very small content of ferro-magnesian minerals. From their mineralogical constitution, it may be inferred that with a low silica percentage there is a comparatively high content of alkalies, iron oxides, and alumina, together with a deficiency in lime and magnesia, in the chemical analysis.

Since the type-rocks from Skye were described mugearites have been found in Mull and Eigg,* in East Lothian and Midlothian, and also in the Campsie and Kilpatrick Hills.† The

* *Summ. Progr. Geol. Sur.* (1905), Analyses p. 73.

† *Summ. Progr. Geol. Sur.* (1906), p. 91.

Digitized by Google

occurrences in the Midland Valley belong to Lower Carboniferous lavas, and are believed to be flows, whereas the type-rocks from Skye are members of composite sills of Tertiary age. Dr. Flett has recently described the mugearites of the Lothians.* They differ from the Skye rocks in being much less fresh, and in containing more orthoclase and less olivine. There are also porphyritic types with phenocrysts of labradorite and decomposed augite. The rocks from North Third agree very well in petrographical characters with those from the Lothians, but do not contain the peculiar hornblende or biotite flakes characteristic of the latter rocks. Like the mugearites of the Campsies and Kilpatricks, they occur towards the top of the Lower Carboniferous lavas.

EXPLANATION OF PLATES.

PLATE XIII.

Fig. 1.—Photograph showing the excavation through the escarpment of Bed O. The alternating beds of lava and tuff are well shown. Bed L is three feet thick.

Fig. 2.—Photograph of a very perfect "back" or fracture surface developed by blasting. Numerous other concentric surfaces are visible to the left. A two-foot rule gives the scale.

PLATE XIV.

A longitudinal section from E.W. along the trench, showing the alternations of lava and tuff, the irregular surfaces of the flows, and numerous hollows filled with boulder-clay. A small plan shows the exact location of the trench.

* *Summ. Progr. Geol. Sur.* (1907), pp. 119-126.

Digitized by Google

No. XXI.—Notes on the Shore Section at Brodick and Corrygills, Arran. By James W. Reoch.

[Read 14th May, 1908.]

The island of Arran has long been recognised as an ideally happy hunting-ground for the geologist, and not the least interesting portion of it is the shore section from Brodick *via* Corrygills to Clauchlands Point, and the eastern part of the ridge of the Clauchland Hills, visited by members of this Society on the 20th April, 1908. To the young geologist in particular is this section of value, as here there is exposed within a distance of a few miles a continuous section of rocks, presenting very clearly, and in such short space, many features of great interest, such as dykes and sills, and their relations with the sedimentary rocks, also faulting, false-bedding, weathering, marine erosion, and ice action.

The sedimentary rocks are red sandstones and conglomerates of Lower Triassic age, with a general S. to S.W. dip, much faulted, and intersected by numerous dykes—mostly basic—and invaded at many points by sills of felsite, pitchstone, quartz-porphyry, and dolerite.

The age of these sedimentary rocks was long disputed, and they have been variously regarded as of Old Red Sandstone, Carboniferous, or New Red age; but the question seems to have been definitely settled (according to the "Memoir of the Geological Survey") in 1894, when they were found to be unconformable to the Carboniferous formation. At Corrie, and near Brodick, they are seen to rest on the Lower Coal Measures, and in Ben Lister Glen on the Corrie Limestone, hundreds of feet lower in the Carboniferous formation; while at Machrie, on the west coast, they lie directly on the Old Red Sandstone, all the Carboniferous rocks having disappeared. Dr. Bryce stated that he discovered a true Carboniferous fossil, a species of *Orthoceras*, in the cliffs at Corrygills, too imperfect for identification of the species, but perhaps the *O. cinctum* of Professor Phillips, from which he argued that these rocks were

Digitized by Google

of Carboniferous age. According to the Survey Memoir, however, "No fossils, except some derived from the Carboniferous formation, have as yet been found in these newer red rocks, so that there must be a little uncertainty about their exact age, . . . but the finding of a portion of the upper marls immediately connected with beds of Rhætic age in a fragment of the Ard Bheinn volcanic agglomerate fixes pretty definitely the Triassic age of the upper division of the formation."

These unconformable and overlapping red strata are divided into two great groups—the Upper and the Lower Trias—with the former of which we are not here concerned. The Lower Trias in Arran has been subdivided into—

Lower Trias.
4. Light-coloured and yellowish sandstones, sometimes red, with calcite in cavities.
3. Reddish sandstones with some conglomerates.
2. Conglomerates alternating with sandstones.
1. False-bedded red sandstones of Brodick and Corrie.

The three lowest subdivisions are well exposed in the Brodick to Corrygills section.

Starting from Brodick pier eastward, our way lies along the old 25-feet raised beach, which is a well-marked feature around the coast line of the island. Here it forms a broad platform of rocks planed down by the action of the sea, and backed inland by cliffs finely clad with ivy and ferns, and crowned with wild wood, and in which water-worn caves occur here and there. At Brodick Pier we are on No. 2 subdivision—the alternating brecciated conglomerates and sandstones. The conglomerates are very similar to those of the Upper Old Red Sandstone, which occur to the north of Corrie, and are largely made up of fragments of metamorphic rocks, viz., vein quartz and angular fragments of schist, with occasional pebbles of quartzite.

Proceeding along the coast from Brodick Pier S.E. to Clauchlands Point we pass successively over the three lowest subdivisions in an ascending series, interrupted by faults which repeatedly bring up the lower beds, causing us, so to speak, to begin at the bottom all over again, and thus impressing the details all the better on our minds. The strata here have

Digitized by Google

a general southerly dip of from 10 degs. to 20 degs. Immediately E. of the pier a fault, ranging N. 25 degs. E., brings up the lower false-bedded sandstones (No. 1) against the conglomerate. The sandstone continues for about 300 yards E., and is then cut off by a fault coinciding with the course of a dyke ranging N. 25 degs. W., throwing down the conglomerate again on the E. Following the conglomerate for 500 yards eastward, the next fault, with a downthrow S.W., again brings the lower sandstone to view; this continues for 300 yards, and is overlaid by conglomerate till opposite the point where the road from Strathwillan comes down to the shore, where a powerful fault N. 30 degs. E. brings up the lower sandstones again. This fault, which must have a downthrow W. of several hundred feet, has the effect of raising the cliffs much in height at this point, the conglomerate having been raised high above the present top of the cliffs, and we do not see it again till about half a mile further S.E., near Corrygills Point, the southerly dip of the beds bringing it again down to the shore. Clean sections of the false-bedded sandstones are exposed in the high sheer cliff behind the raised beach.

Besides these major faults just noticed, the sandstones all along this part of the shore, from Brodick Pier eastwards, are much intersected by minor faults, fractures, and lines of crush, running in all directions, some beautiful examples of which may be seen where the rocks show clean vertical sections. These minor faults and fractures have in many cases been infiltrated with what appears to be a more siliceous material, which resists disintegration, and where the softer sandstone has weathered away stands up in prominent ribs and ridges. In some places these fault fissures would appear to have opened again and again and been filled with the harder vein material, until a thickness of more than a foot has been attained, and now, when the softer sandstone on either side has been denuded, they stand up as dykes of hard sandstone, stratified parallel to the sides of the fault fissures, and in some places are over 6 feet in height, pursuing a straight course for many yards. In other cases the fault fissures have been filled by dykes of basic rock, which in this part of the shore are very numerous, as many as sixty having been counted between Brodick and

Digitized by Google

Clauchlands Point. These dykes are seen to traverse the rocky platform, and most of them may be traced in the cliffs above, either by deep gashes or by projecting walls, or level with the cliff face. The course of one of these near the Strathwillan Road may be seen as a deep narrow cleft in the cliff about 2 feet broad, on the beach platform below it has dwindled to 1 foot, and tracing it seaward it dies out completely as a mere crack or line of fracture in the strata. It gives off a small branch to the E., which also dies out completely on the surface after a course of a few yards. Here also a beautiful example of a miniature dyke may be seen, of only about 2 inches in breadth, but which pursues a curved course of many yards through the sandstone strata and runs out to sea. The weathering of these basic dykes is of interest, as well as their effects on the sandstone into which they have intruded. As a rule, the sandstone has been much hardened and the red colour discharged, so that it becomes white for sometimes a considerable distance. One notable instance is seen near Brodick Pier, where on the eastern side of a dyke the sandstone is whitened for 30-40 feet. Where the alteration on the sandstone has been great it resists disintegration, and the dyke appears to wear more rapidly. On the other hand, an instance of the contrary may be noticed, where the sandstone appears to be hardly altered, and the igneous rock stands up as a true dyke. Another remarkable instance may be observed where a basic dyke has so altered the sandstone on either side of it as to render it distinctly prismatic in structure for about a yard, and here the sandstone stands up on the sides of the weathered dyke as two massive walls. Beautiful examples also may be seen of the clean, straight, containing walls of the hardened sandstone, where the dykes have been deeply weathered out, some of these forming perfect little natural harbours on the coast.

Near Corrygills Point we come to an interesting acid sill or dyke of felsite, which appears to have been intruded into a fault fissure between beds of underlying conglomerate and overlying sandstone. The rock is of a pale yellow colour, the base being of a uniform texture with quartz pieces imbedded, and is divided irregularly into prisms perpendicular to the

Digitized by Google

lower surface of the sill; the structure is seen to be schistose at right angles to the joints in places. The breadth exposed on the shore is 30-40 yards. It is seen also in section in the cliff inland. Between its lower surface and the underlying conglomerate there has been intruded a vein of basalt, having the same inclination as the felsite, and in some places thin bands of conglomerate are interposed between the basic rock and the felsite. The posterior origin of the basic rock seems thus to be indicated. The conglomerate underlying the basic rock is much indurated, but the sandstone overlying the felsite sill has been little altered. According to the Survey Memoir, most of the basic dykes of Arran are more recent than the granite, which is now considered as of Tertiary age. They penetrate the coarse acid and basic sills, are less numerous in the fine-grained basic sills, and are almost entirely absent in the felsite sheets, pointing to these last as being the most recent of all the intrusive igneous rocks of Arran.

During our progress along the shore we may notice many strayed water-worn blocks, the majority of them of granite, and some of large size. These, as we go east, are seen to increase in number, till at Corrygills Bay the shore is literally crowded with them. They are mostly of the coarse granite of the interior of the island to the north, and have evidently been transported by the agency of ice. This would seem to be a point at which the ice in its passage from the Goat Fell range had dropped its burden of boulders; or may they have been weathered out of the boulder-clay during the cutting out of the raised beach?

Prominent amongst these appears on the foreshore the great granite boulder of Corrygills. The dimensions at the base are 21 feet by 12 feet, and the height 15 feet. Its weight has been estimated at 210 tons. It is composed of the coarse-grained granite of the Goat Fell range, with veins runnning through it of aplite or fine-grained granite.

Here we are in view of the ridge of the Clauchland Hills to the south, composed of Triassic Sandstones, still dipping generally southwards, and capped by a sill of dolerite, which slopes down and runs out to sea eastwards at Clauchlands Point.

Digitized by Google

Resuming our way along the coast to the S.E., we have now passed up to the third subdivision of the Lower Trias, consisting almost entirely of red sandstone moderately coarse, with only occasional pebbly bands, and comparatively little false-bedding. The dip inclines more to the W. here and increases in amount, in some places being as high as 30 degs. or 40 degs., and the strike being parallel to the shore. South of Corrygills Bay the dykes are numerous and traverse the sandstone in every possible way, intersecting one another at various angles, branching and bifurcating, lesser ones lost in larger. One of them, about 14 feet wide, is seen to run for about a mile in a straight line parallel to the coast till lost under the sea near Clauchlands Point. These may be best examined at low tide.

At this point of the shore the sandstone is seen to weather curiously into a honeycomb-like structure, and blocks of this, Nature's sculpture, may be seen transported to ornament the gardens of some of the cottages in the neighbourhood. No art could excel this natural sculpture in beauty.

As we proceed towards the base of Dun Fionn we come upon an interesting sill of felsite, accompanied along part of its lower margin by a vein of pitchstone. The felsite sill at its centre is an almost pure white homogeneous rock, much resembling outwardly an indurated sandstone. At its edges, on both upper and lower surfaces of the sill, the rock, however, assumes a remarkable spherulitic structure; on the lower or northern margin of the sill, in particular, this structure is at one spot very strongly developed, and beautiful hand specimens of the rock may be obtained showing both the weathered, pea-like forms of the spherules, and clean sections of the spherules where the rock has been freshly fractured. The spherules exhibit a radiated fibrous structure, the radii sometimes diverging from a point and sometimes from a solid nucleus, the radiations being of pure quartz. Dr. Bryce, in his "Geology of Arran," quotes Dr. MacCulloch's description of the rock in full, but space does not permit the quotation of it here. He further states that "mineralogists have long regarded this curious rock with much interest, and various opinions have been held regarding its true relations, some considering it as allied to claystone and others to pitchstone."

Digitized by Google

Mr. Alfred Harker describes the rock as a spherulitic felsite of a dull grey aspect, the little spherulites appearing as dead white spots $\frac{1}{40}$ to $\frac{1}{8}$ inch in diameter, often with a dark nucleus and a dark border. There is a flow structure partly marked by lines of spherulites. In this relation he states that "numerous geologists have noticed in Arran the occurrence of *felsitic rocks* in close association with pitchstones. In the older literature these rocks figure usually under the names 'hornstone' and 'claystone.' Some which have been analysed have a chemical composition not essentially different from that of the pitchstones, and the intimate association of the two rocks decidedly suggests that they are closely cognate and are in some cases parts of the same rock body, the one having assumed a finely crystalline and the other a vitreous state. Assuming this, it remains a question whether the finely crystalline texture is original, or is the result of devitrification of the pitchstone. . . . The remarkable micro-structure of the pitchstones may not improbably become obscured or obliterated by secondary changes when the glassy character is lost, and the absence of perlitic fissures in most of the Arran pitchstones usually precludes a criterion which has often been relied upon in other districts as indicating a former vitreous condition in rocks now cryptocrystalline or microcrystalline."

Examining the sill as exposed in the cliff section inland, we can clearly trace the felsite passing into the spherulitic condition, then being underlaid by a distinct band of the glassy-like, bottle-green pitchstone. The pitchstone appears to be a distinctly separate intrusion here from the felsite.

Passing on under the base of Dun Fionn we notice a broad dyke of reddish quartz-porphyry cutting straight through the foreshore and running out to sea.

Above us, on the precipitous hillside, a great vein of columnar pitchstone is conspicuous, forming a broad band in front of the sandstone cliff. It occupies a slanting position in the cliff generally parallel to the sandstone strata, and dipping with them to the S.S.W. at nearly 30 degs. Climbing up to examine it, we find it to be about 13 feet thick, and of the usual dark, bottle-green colour. On the smooth, weathered surface undulating lines of flow are well shown. It is visible

Digitized by Google

for about 150 yards on the hill face, and is seen to clearly cut the sandstone, but it has produced little alteration, on which account there has been much dispute as to its intrusive character. Descending to the shore again, we pass along under a range of cliffs forming the edge of a great sill of rudely columnar dolerite capping the sandstone and extending westward along the ridge of the Clauchland Hills. The foreshore here is strewn with huge masses of the shattered columns which have fallen from the cliffs above. As we approach Clauchlands Point the ridge runs down seaward, the dip of the sandstone beds increases near the junction, and is in one place as much as 60 degs., probably the effect of the intrusion of the great sill of dolerite there. A fine intrusive junction is here seen on the shore, the underlying red sandstone being intensely hardened and changed to a white quartzose rock. The intrusive sill is in some places a coarse, gabbro-like rock, with large crystals of augite, olivine, and plagioclase, and without any groundmass, passing elsewhere into a more compact rock of a basaltic type, which latter is the character of the rock that prevails over a great part of its extent. We now continue on the dolerite round Clauchlands Point into Lamlash Bay, where the sandstone is again seen overlying the sill, here dipping to the S.S.E. at a gentle inclination of about 10 degs. The bay of Lamlash appears to have been entirely carved out of these Lower Triassic Rocks, which from this point southwards occupy the whole eastern shore of the island.

Striking now up the brae westward from Clauchlands Point along the dolerite ridge of the Clauchland Hills, we reach Dun Fionn, about 600 feet above sea-level, said to be the site of an ancient vitrified fort, and here, if the weather is clear, it is well worth while to pause and gaze around upon the magnificent prospect which has gradually been unfolding itself to our eyes as we ascended. The view is both grand and extensive. In the distance to the north we see the lofty peaks of the western Highlands, prominent among which appear Ben Lomond and the Arrochar Bens; then, turning gradually southward, we take in with an uninterrupted sweep of the eye the whole stretch of the Ayrshire coast, and in the distant S.E. the Galloway mountains. Nearer at hand we look

Digitized by Google

Fig. 1.—Course of Weathered Dyke in Triassic Conglomerate, near Corrygills.

Fig. 2.—Major and Minor Faulting in Triassic Rocks, near Brodick.

Digitized by Google

Digitized by Google

over the blue waters of the Firth to Bute and the Cumbraes; and northwards arise the great riven granite peaks of Arran, seen from this point to the best advantage; while to the south-east the huge felsite boss of Holy Island guards the bay of Lamlash, and the coast line stretches away to the cliffs at Dippin. Appearing almost directly below us, a great part of the shore section which we have traversed now appears spread out like a geological map, and from this superior view-point it is interesting to be able to trace out all the intersecting dykes which we have already examined at close quarters.

Again passing on westwards, we may examine two more sills of pitchstones intruded at a high level among the sandstone of the Clauchland Hills; then a short ascent takes us to the summit of Dun Dubh, which is composed of a large sill or boss of quartz-porphyry protruding from the north side of the main ridge of the hills. The rock is a quartz-porphyry of a light grey colour, and shows fine columnar structure. The grey microcrystalline groundmass of felspar and interstitial quartz contains conspicuous crystals of glassy orthoclase, and also of quartz, imbedded in it, many of the latter presenting well-shaped bi-pyramidal forms. It shows a fine face of columns on the N.W. side, having a singular diverging, fan-shaped arrangement. On the summit the columns are disposed in an almost horizontal position lying N.E. to S.W., and their ends are cut off uniformly to the W., forming a low cliff some 15 feet in height.

A day's geological outing may be fitly ended at this point, and the return made by the road to Brodick. The section thus briefly described is one teeming with interest (as what corner of Arran is not?), and is well worth a closer and more careful examination. During our walk back we have before us the impressive view of the grand form of Goat Fell, with the great grim granite peaks around him—apparent "types of permanence" as viewed from this distance; but, to those who have embraced them closely, now seen to be so rapidly crumbling away—falling and following their doom of dissolution.

Digitized by Google

PROCEEDINGS FOR SESSION 1907-1908.

SOCIETY'S ROOMS, 207 BATH STREET, 10TH OCTOBER, 1907.

The first meeting of the fiftieth Session of the Geological Society of Glasgow was held here this evening—Mr. R. W. DRON, *V.P.*, in the chair.

Professor GREGORY drew the attention of the members to the wanton destruction of boulders along the shores of the Gareloch, and it was agreed to forward to the proper authorities a protest against the destruction of landmarks so interesting and so valuable to science. Mr. S. FINGLAND, University photographer, and Mr. G. W. TYRRELL, A.R.C.Sc., exhibited a large series of micro-photographs of rock sections, taken in colour by the new Lumiere process. This is probably the first exhibition of micro-photographs by the new process ever shown, and keen interest was manifested in the fine results obtained. Mr. ROBERT DUNLOP exhibited the following :—(1) Woodocrinus, (2) Ichthyocrinide, (3) Edmondia pentonsis (Hind), (4) Ctenodonta pentonsis (Hind). The specimens were all very fine ones, some being new to science. Dr. J. W. GREGORY, F.R.S., F.G.S., Professor of Geology in Glasgow University, read a paper entitled, " The Great Scandinavian Over-thrust." In several places gneisses and crystalline schists are found resting on rocks that are much less altered. In some cases the age of the lower rocks can be determined as Silurian or Ordovician, and there can be no doubt that we have here the remarkable case of older rocks resting on younger rocks. The explanation of this remained a mystery to Scandinavian geologists, until the clue was given them by the work of Scottish geologists in the Highlands. It is now believed that huge slices of the older rocks have been pushed across the younger ones by powerful over-thrusts. In a recent expedition to Lapland, Professor Gregory took the opportunity of examining some of the sections, and was convinced that the phenomena could only be explained by over-thrusting. Some Scandinavian geologists claim to have traced this thrust for over one thousand miles, but the speaker was of the opinion that the facts were better explained by supposing a number of minor thrusts *en echelon*.

Dr. HORNE, Director of the Geological Survey of Scotland, congratulated Professor Gregory on the clearness with which his views had been put forward. He agreed with the author of the paper that the facts could only be explained by over-thrusting. The demand to be shown a clean cut plane wherever a thrust-plane came to the surface was not legitimate, as

Digitized by Google

this might be obscured by denudation. It seemed to him that overthrusting was in general not a deep-seated phenomenon, for fossils not far below the thrust-plane were not much injured.

A vote of thanks to the contributors of specimens and papers concluded the meeting.

(Signed) DAVID CHALMERS, *V.P.*

SOCIETY'S ROOMS, 207 BATH STREET, 14TH NOVEMBER, 1907.

The second meeting of the fiftieth Session of the Geological Society of Glasgow was held here this evening—Mr. DAVID CHALMERS, *V.P.*, in the chair.

The Minutes of last meeting were read and adopted.

A letter was read from Mr. COWIE enclosing a cheque for £100 as a gift to the Society.

Mr. COWIE suggested that the income should be used to pay the fees of students attending Geological Classes in Glasgow or Govan, but left the Council a free hand in the matter. Mr. SOMMERVILLE moved that the thanks of the Society be given to Mr. Cowie for his generous gift, and this was done with acclamation.

The Annual Reports of the Council, the Treasurer, and the Librarian were read by Messrs. MACNAIR, WIGHT, and SINCLAIR respectively, and showed that the Society still upheld its reputation for valuable scientific work, and was in a sound financial condition. On the motion of Mr. SOMMERVILLE, seconded by Mr. JOLLY, the reports were unanimously adopted.

The following office-bearers were elected:—Vice-president, Mr. Joseph Sommerville.

Members of Council—Mr. David Chalmers, proposed by Mr. J. Sommerville and Mr. John Renwick; Mr. G. W. Tyrrell, A.R.C.Sc., proposed by Mr. P. Macnair and Mr. J. Renwick; Mr. R. Dunlop, proposed by Mr. James Neilson and Mr. P. Macnair; Mr. A. Macintyre, F.S.A.A., proposed by Mr. J. Steel and Mr. J. W. Reoch.

ELECTION OF MEMBERS.

As Life Member—Mr. John A. W. Murdoch, Cerode Paxo Mining Company, Morocoeha, Peru, proposed by Mr. P. Macnair and Mr. F. Mort.

As Ordinary Members—Mr. Robert Craig, A.G.T.C., M.I.M.E., Sorn Road, Auchinleck, Ayrshire, proposed by Mr. R. Dunlop and by Mr. F. Mort; Mr. William Nicol, 63 Albert Road, Crosshill, proposed by Mr. William Sinclair and Mr. John Renwick; Miss Agnes T. Neilson, 41 West Cumberland Street, Glasgow, proposed by Mr. James Reoch and Mr. P. Macnair; Miss Amanda F. Kling, 33 West End Park Street, proposed by Mr. P. Macnair and Mr. J. W. Reoch; Mr. James Morrison, 3 Church

Digitized by Google

Road, Ibrox, Glasgow, proposed by Mr. Peter Macnair, and Mr. David Chalmers; Mr. Hall Nicol, Hamilton, proposed by Mr. R. W. Dron and Mr. E. Hall Wight.

As Associate Members—Mr. Andrew J. Davidson, c/o Bruce, 34 Hill Street, Garnethill, proposed by Mr. P. Macnair and Mr. F. Mort. Mr. David Clark, Engineer's Office, Caledonian Railway, Buchanan Street Station, proposed by Mr. P. Macnair and Mr. F. Mort; Mr. John M. Don, c/o Smith, 90 North Frederick Street, Glasgow, proposed by Mr. P. Macnair and Mr. F. Mort; Mr. John T. Glen, 10 Dryburgh Gardens, proposed by Mr. P. Macnair and Mr. F. Mort; Mr. F. Douglas Martin, Barnsford, Kilmacolm, proposed by Mr. P. Macnair and Mr. F. Mort; Mr. Peter Whitton, Bellahouston House, Glasgow, proposed by Mr. P. Macnair and Mr. F. Mort; Mr. Robert Dunlop Brown, jun., Glasgow Main Drainage Works, Partick, proposed by Mr. P. Macnair and Mr. F. Mort; Mr. Alexander Elliot, 87 Hornlea Road, Langside, proposed by Mr. P. Macnair and Mr. F. Mort.

Notice of the folowing Motion was duly given by Mr. WILIAM JOLLY:—"That rule 4, paragraph 4, be amended to read as follows—'That students attending Geological or kindred Scientific classes, by whomsoever conducted and in any premises whatever, shall be eligible for admission as Associates of the Society (to end of paragraph).'"

Mr. JAMES NEILSON exhibited bones and teeth of a large Carboniferous shark, Cladodus striatus, a large pecten, Streblopteria lævigata, and other interesting fossils. Mr. J. W. REOCH exhibited a number of photographs of the Arran granites. The slides were remarkable both for their beauty of execution, and the splendid manner in which they illustrated the geological features of the district. Mr. R. W. DRON read a paper entitled "Iron and Copper Mining in Shetland." [See *Trans.*, vol. xiii., pt. 2, p. 165.]

(Signed) JOSEPH SOMMERVILLE.

SOCIETY'S ROOMS, 207 BATH STREET, 12TH DECEMBER, 1907.

The third meeting of the fiftieth Session of the Geological Society of Glasgow was held here this evening—Mr. JOSEPH SOMMERVILLE, *V.P.*, in the chair.

The Minutes of the previous meeting were read and adopted.

The following Members were elected:—

As Ordinary Members—Mr. R. Harper, Early Braes, Shettleston, proposed by Mr. P. Macnair and Mr. F. Mort; Mr. Duncan Smith, 3 Albion Street, Paisley, proposed by Mr. P. Macnair and Mr. F. Mort; Rev. C. A. Hall, Meeresbrook, Meikleriggs, Paisley, proposed by Mr. P. Macnair and Mr. M. Blair; Mr. Andrew G. Murray, c/o Messrs. Brownlee, Watson & Beckett, 225 West George Street, proposed by Mr. P. Macnair and Mr. F. Mort; Miss Bessie Jolly, M.A., 21 Princes Street, Pollokshields, proposed by Mr. William Jolly and Mr. P. Macnair; Miss Dorothy Tullis, Aytoun

Digitized by Google

House, Dowanhill, Glasgow, proposed by Mr. William Jolly and Mr P. Macnair.

As Associate Members—Mr. David Hendry, Thomson Avenue, Johnstone, proposed by Mr. P. Macnair and Mr. F. Mort; Mr. Adam Hogg Bowie, 7 Buchanan Gardens, Mount Vernon, proposed by Mr. P. Macnair and Mr. F. Mort; Mr. Gled. H. Brayne, Glencliffe, Irvine, proposed by Mr. P. Macnair and Mr. F. Mort; Miss Nan. Ormiston Neil, 87 Stanmore Road, Glasgow, proposed by Mr. P. Macnair and Mr. F. Mort; Mr. Robt. Boyle, c/o Mrs. Rankin, 113 Renfrew Street, proposed by Mr. P. Macnair and Mr. F. Mort.

A letter from Dr. PEACH was read, stating that he was still under the doctor's care and that he could not hope to be at any meetings for some time. The Secretary was asked to convey to him the sympathy of the Society, and the hope that he would soon be restored to perfect health.

Having given notice of his intention last meeting, Mr. WILLIAM JOLLY moved—

"That rule 4, paragraph 4, of the constitution be amended to read as follows:—'That students attending Geological or kindred Scientific classes, by whomsoever conducted and in any premises whatever, shall be eligible for admission as Associates of the Society (to end of paragraph).'"

There being no seconder, the motion was therefore dropped.

Mr. DUNLOP and Mr. NEILSON referred to the death of Mr. Murray, Rector of Kilmarnock Academy, and spoke of the great interest he always took in natural science, and of his fine personal character.

On the motion of Mr. SOMMERVILLE, Mr. Pearson and Mr. Renwick were appointed auditors.

Mr. JAMES NEILSON read a paper entitled "Among the Swiss Glaciers, with Special Reference to Scottish Glaciation." The speaker recalled the former vigorous debates that always arose on the frequent occasions when glaciation was before the Society. He then gave a description of Lucerne and the surrounding country. He next passed to the Bernese Oberland and described the snowfields and glaciers of that district. Mont Blanc, the Mer de Glace, and the Glacier de Bossons were then described in some detail. Mr. Neilson then showed how the Aletsch Glacier has dammed back a lake of water at its side, the well-known Marjelen Sea. The application of this to the parallel roads of Glen Roy was then discussed. Finally an interesting description was given of the Rhone Glacier and the source of the river Rhone. The paper was splendidly illustrated by a large number of fine lantern slides.

(Signed) J. W. GREGORY.

SOCIETY'S ROOMS, 207 BATH STREET, 9TH JANUARY, 1908.

The fourth meeting of the fiftieth Session of the Geological Society of Glasgow was held here this evening—Professor GREGORY, F.R.S., in the chair.

Digitized by Google

The Minutes of the previous meeting were read and adopted.

Professor GREGORY referred to the death of Lord Kelvin, and stated that the Council proposed sending a letter of sympathy to Lady Kelvin.

The following members were elected :—

As Ordinary Members—Mr. Samuel Becket, Lethenvale, Hamilton, proposed by Mr. William Jolly and Mr. Peter Macnair; Mr. James Stratton, M.A., Mavis Mill, Cambuslang, proposed by Mr. William Jolly and Mr. Peter Macnair.

Professor J. W. GREGORY, D.Sc., F.R.S., read a paper entitled "Lord Kelvin's Contributions to Geology." [See *Trans.*, vol. xiii., pt. 2, p. 170.]

Mr. F. MORT, M.A., B.Sc., F.G.S., Honorary Secretary, then read a paper entitled "The Passage of a Dolerite into a Hornblende Schist.' [See *Trans.*, vol. xiii., pt. 2, p. 187.]

Mr. JAMES STARK read a paper entitled "Notes on the Geology of South-East Arran." [See *Trans.*, vol. xiii., pt. 2, p. 191.]

(Signed) R. W. DRON, *V.P.*

SOCIETY'S ROOMS, 207 BATH STREET, 13TH FEBRUARY, 1908.

The fifth meeting of the fiftieth Session of the Geological Society of Glasgow was held here this evening—Mr. R. W. DRON, *V.P.*, in the chair.

The Minutes of the previous meeting were read and adopted.

The CHAIRMAN announced that Lady Kelvin had written to the Society thanking them for their letter of sympathy on the death of Lord Kelvin.

The following members were elected :—

Honorary Member—Professor T. G. Bonney, D.Sc., LL.D., F.R.S., F.G.S., 9 Scroope Terrace, Cambridge.

As Associate Members—Mr. Matthew M. Monie, M.A., Kelvinside Academy, Glasgow, proposed by Mr. Sinclair and Mr. Macnair; Mr. Bertram J. Hale, Auchentorlie Villas, Bowling, proposed by Mr. Macnair and Mr. Mort.

Mr. SOMMERVILLE gave notice that at next meeting he would move—"That £15 of the Society's funds be devoted to Library purposes during the current session."

Mr. ROBERT DUNLOP exhibited specimens of fossil crustaceans, including some remarkably fine examples of Tealliocaris and Anthrapalæmon. He referred to the various collections of crustacea in Scotland, and gave an account of the recent advances that have been made in the study of this group.

Mr. J. W. REOCH exhibited a series of lantern slides of photographs taken at localities recently visited by the Society. Some exceedingly fine examples of mountain photography were shown, a branch in which the exhibitor is an acknowledged expert.

On behalf of Mr. JOHN SMITH, the Secretary exhibited a specimen of

Digitized by Google

teruelite from the Heads of Ayr. Remarks on the specimen were made by Mr. Dunlop and Mr. Boyle.

Mr. G. W. TYRELL, A.R.C.Sc., University, assistant in geology, read a paper entitled "Petrographical Notes on a Dyke crowded with Rock Fragments near Barrhead." [See *Trans.*, vol. xiii., pt. 2, p. 195.]

(Signed) JOSEPH SOMMERVILLE.

SOCIETY'S ROOMS, 207 BATH STREET, 12TH MARCH, 1908.

The sixth meeting of the fiftieth Session of the Geological Society of Glasgow was held here this evening—Mr. JOSEPH SOMMERVILLE, *V.P.*, in the chair.

The Minutes of previous meeting were read and adopted.

Mr. R. W. DRON, A.M.I.C.E., exhibited fragments of bones of Bos longifrons encrusted with vivianite. The bones were found in a shaft sunk in the valley of the Clyde, near Motherwell. They were imbedded in sand forty feet below the surface, and rested just above the level of the boulder clay.

Remarks were made by Mr. Macnair, Mr. Dunlop, and Mr. Jolly.

Mr. R. BOYLE, B.Sc., A.G.T.C., read a paper entitled, "The Occurrence of Ultra-basic Rocks in the Igneous Intrusions of the Lugar and Cumnock District." [See *Trans.*, vol. xiii., pt. 2, p. 202.]

SOCIETY'S ROOMS, 207 BATH STREET, 9TH APRIL, 1908.

The seventh meeting of the fiftieth Session of the Geological Society of Glasgow was held here this evening—Mr. R. W. DRON, *V.P.*, in the chair.

The Minutes of the previous meeting were read and adopted.

The following gentleman was elected an ordinary member:—

Mr. William S. Watson, sub-editor of *Lanarkshire*, Brandon Street, Hamilton, proposed by Mr. William Jolly and Mr. F. Mort.

Mr. R. DUNLOP exhibited a specimen of Alethopteris valida, a species new to the West of Scotland. He stated that the first drawings of the genus Alethopteris were to be found in the "History of East Kilbride," by David Ure. The species exhibited had been known in England for a long time, but had only recently been determined for the West of Scotland from an examination by Mr. Kidston, F.R.S., of the specimen exhibited, which came from Mr. Dunlop's collection. Mr. JOHN SMITH read a paper entitled "The Discovery of Upper Coal Measure Fossils in Ayrshire." [See *Trans.*, vol. xiii., pt. 2, p. 224.] Mr. WILLIAM JOLLY read a paper entitled, "Notes on Carboniferous Fossils gathered near Dalry, Ayrshire, in 1859-60." At the outset Mr. Jolly gave a graphic description of how he had been attracted to the study of geology and the difficulties he had met in attempting to name the fossils gathered in Ayrshire. These difficulties had been removed by the help of the late Dr. John Young,

Digitized by Google

Curator of the Hunterian Museum, Glasgow University. Mr. Jolly gave many interesting reminiscences of Dr. Young's enthusiasm for the science, and the help he was always eager to give to any earnest student of Geology.

The fossils collected by Mr. Jolly were exhibited, and he stated that they were to be presented to Kelvingrove Museum.

Mr. PETER MACNAIR, F.R.S.E., F.G.S., read a paper entitled "Notes on an Ocellar Dolerite from Craigie Hill, Ayrshire." [See *Trans.*, vol. xiii., pt. 2, p. 235.]

(Signed) J. W. GREGORY.

SOCIETY'S ROOMS, 207 BATH STREET, 14TH MAY, 1908.

The eighth meeting of the fiftieth Session of the Geological Society of Glasgow was held here this evening—Professor GREGORY in the chair.

The Minutes of the previous meeting were read and adopted.

Mr. PETER MACNAIR, F.R.S.E., F.G.S., exhibited crystals of calcite from Thorntonhall Quarry, East Kilbride. The crystals showed a scalenohedron capped with a prism and a rombohedron. Mr. F. MORT exhibited a number of photographs illustrating South African geology, forwarded for presentation to the Society by Mr. A. L. du Toit, Geological Commission of Cape Colony. Mr. JAMES W. REOCH read a report of the excursion to Brodick, Arran, and Mr. R. W. DRON, C.E., read a report of the excursion to Motherwell. Mr. N. MARTIN, A.G.T.C., B.Sc. and Mr. G. W. TYRRELL, A.R.C.Sc., read a paper entitled "On a Puddle Trench Section near Bannockburn, with Notes on the Geology of the Surrounding District." [See *Trans.* vol. xiii., part 2, p. 240.]

COUNCIL REPORTS.

REPORT OF THE COUNCIL FOR 1903-1904.

As has been its annual custom for many years, the Council beg to present to the members at the Annual General Business Meeting in 1904 their Report upon the work and progress of the Society during the year just come to a close—October, 1903, to September, 1904.

MEMBERSHIP.—During the year the membership has more than held its own level as compared with recent years, and therefore the number of names on the roll is slightly in excess of the same period last year. While this is so far a source of gratification to the Council, it should not be supposed that they are satisfied with the number of members belonging to the Society. They still think that that might be and ought to be considerably increased, and they hope that each member now on the roll will do his best to bring in one or two of his friends.

ASSOCIATE MEMBERSHIP.—This scheme, which has certainly been of benefit to the students in geological and mining classes, has been con-

Digitized by Google

tinued during the year, though the number of Associates has not been so large as might have been expected. With the assistance of the lecturers in the various institutions of the city which give prominence to geological classes, it is to be hoped that in the future more Associates will join the Society.

The FINANCES are, as your Hon. Treasurer, Mr. Hall Wight, will tell you in his statement to be submitted this evening, in a sound and satisfactory condition.

The LIBRARY has been considerably made use of during the year, and in his Report of the work your Hon. Librarian, Mr. M'Lennan, will submit particulars. A number of the new publications treating of geological work have been added to the shelves, and a good many additions have come in through exchange.

The MEETINGS of the Society held during the year were nine in number, and were all well and some of them largely attended by members and their friends. The material brought forward at them was quite sufficient to fill the whole time of the meetings available, and, with one exception, was entirely the contribution of members of the Society. The Council by no means undervalues the papers, &c., which have been brought before the meetings in previous years by outside friends, but it used to be occasionally alleged that too much reliance was being placed on such contributions, and that the members were not sufficiently exerting themselves on behalf of the meetings. It is, therefore, very gratifying to be able to note a change in the desired respect.

The PAPERS read during the year were in number as follows :—

12th Oct., 1903.—(1) "Notes on Recent Excavations in Glasgow," by John Wallace.

(2) "On the Spheroidal Weathering of the Trap Dyke, near Bishopbriggs," by John Wallace.

"Notes on the Recent Meeting of the British Association at Southport," by J. B. Murdoch.

"The Intrusive Dolerites of the Glasgow District," by Peter Macnair. This paper was founded on the fine series of microscopic slides prepared by Mr. Arthur Pratt, long an active member of the Society, and which has recently been given to the Kelvingrove Museum by Mr. Pratt's family.

12th Nov., 1903.—"Recent Work in Camp Siluria amongst the Silurian Rocks of Lanarkshire," by David Nimmo. Illustrated by lantern slides.

10th Dec., 1903.—"The Structure of the Loch Lomond and Aberfoyle District," by A. L. du Toit. A revised edition, contributed by the author, and read by the Hon. Secretary, Mr. Macnair. It was illustrated by lantern slides.

14th Jan., 1904.—"The Structure of Igneous Rocks," by F. Mort, B.Sc., F.G.S., &c. Illustrated by lantern slides.

Digitized by Google

11th Feb., 1904.—"The Highland Border Faults in the Island of Arran," by James Stark, *V.P.* Illustrated by maps and specimens.

"Notes on a Recent Excursion to Leadhills and Wanlockhead," by John Smith.

10th March, 1904.—A lecture on "New Zealand: the North Island and its Wonderland," by Robert Dunlop. Illustrated by specimens and by lantern slides.

14th April, 1904.—"On Trap Sills," by John Smith. Illustrated by diagrams and specimens.

"Notes on Fossiliferous Shales underlying the Arden Limestone at Daireband," by James Neilson (1). Illustrated by specimens.

5th May, 1904.—"The Modes of Occurrence and Origins of Intrusive Rocks," by J. G. Goodchild, F.G.S. Illustrated by diagrams and specimens and by lantern slides.

2nd June, 1904.—"Crystallised Carbonite: a Mineral new to Scottish Carboniferous Rocks," by John Smith.

"Some Difficulties of the Young Geologist," by Matthew Blair, *V.P.*

SPECIMENS.—In addition to the specimens brought forward as illustrative of papers, a considerable number was shown separately, some with notes and remarks. The Council have always looked on this as a good feature of the Society's work, as yielding an opportunity for younger or less skilled members to contribute even to a small extent.

As regards the particulars sent out to members about the excursions, a new departure was taken this year. Previously any details given were put on a card, but the space allowed for each was so small that justice could hardly be done in the descriptive notes. Following the line of some of the English societies, a small booklet was issued, giving a considerable amount of detail regarding the district of each excursion, and therefore of some use to all those members who might not be acquainted with the locality. Possibly this is a feature which might be still further amplified in future seasons.

The TRANSACTIONS.—A new part, containing an important paper by Mr. Goodchild on "The Natural History of Scottish Zeolites," was issued in March. Another part, completing vol. xii., is partly printed, and will be issued, it is hoped, by the beginning of the New Year.

APPOINTMENT OF A PROFESSOR OF GEOLOGY TO THE NEW CHAIR OF GEOLOGY IN THE UNIVERSITY OF GLASGOW.—An event of great interest to the members of this Society is the endowment of a new Chair of Geology in the University of Glasgow, and the appointment of a Professor to fill it. Dr. J. W. Gregory, F.R.S., has a high reputation for his attainments, and his advent in Glasgow will most certainly influence the study of Geology. The Council have no doubt that the new professor will interest himself in the Society's work and welfare, and they hope to be able to give him a hearty welcome to its meetings at a very early date.

Digitized by Google

REPORT OF THE COUNCIL FOR 1904-1905.

The Council of the Society have again the pleasure of submitting to the members at the Annual General Business Meeting a Report on the work of the past year, the forty-eighth of the Society's existence.

The membership has been much the same as the average for late years, neither increasing nor diminishing very much. Those who are at present members of the Society have to a large extent this matter in their own hands, and the Council believe that if each member would try and induce his friends to join the Society, the membership roll would soon receive considerable accessions. The annual appeal has been sent out with the October circular, and it is to be hoped that each member will make an endeavour to add to the ranks of the Society. At present it seems to stand particularly much in need of an infusion of fresh blood, as many of the active members who did so much for the Society during its past history have died within the last ten years, and when we look around it seems as if there were none to fill their places. The Council believe that something ought to be done to foster a spirit of research amongst the younger members who are receiving systematic instruction in Geology and Mineralogy both at the University and the Technical College. A large number of students attend these classes, and if something could be done to direct their attention towards the unexplored fields that yet remain in the Clyde Valley, much good work might yet be accomplished by the Society.

FINANCE.—The finances will be reported on by your Hon. Treasurer, Mr. HALL WIGHT, and nothing further need be said here. Unfortunately, owing to the cause already referred to, the Society's income is by no means what it ought to be.

LIBRARY.—The Library continues to be made use of to a fair extent, a considerable number of Associate Members being readers who take advantage of its valuable stores for the purposes of study. The room, however, is altogether inadequate for the proper classification of the books, but now that several societies have found rooms elsewhere it is hoped that more space will be placed at the disposal of the Society for the proper arrangement of the books. This matter will, however, be more fully reported upon by your Hon. Librarian, Mr. WM. SINCLAIR.

MEETINGS.—The meetings of the Session, ten in number, were well attended, and a large number of interesting papers were read and discussed, and a considerable variety of specimens were brought forward for exhibition and remark. Among the papers submitted during the Session may be mentioned the President's valuable address upon "Some New Points in the Geology of Dunnet Head"; Professor J. W. Gregory's paper on "The Glaciation of a Limestone Surface at Lugton, Ayrshire"; Mr. James Currie's address on "The Fæöre Islands"; Mr. Colin Livingston's paper entitled "Further Consideration of the Problems presented by the Parallel Roads of Lochaber and various proposed Solutions"; Mr. Mort's paper upon "The Extension Westwards of the Necropolis Intrusion"; Mr. Macnair's paper

Digitized by Google

on "The Outcrop of the Posidonomya, Punctatella, and Estheria Youngii Beds in the Waukmill Glen," and others by Mr. James Neilson, Mr. Stark, and Mr. Main.

EXCURSIONS.—The excursions of the season were as follows :—

The New Collieries at Olive Bank and New Craighall, Niddrie, Midlothian—24th March.

South Queensferry, Linlithgowshire—7th April.

Aberfoyle, Perthshire—7th April.

Lesmahagow, Lanarkshire—16th April.

Kilmacolm, Renfrewshire—21st April.

Murroch and Auchenreoch Glens, Dumbartonshire—12th May.

Scotstoun West—16th May (Evening Excursion).

Turnberry, Ayrshire—24th May.

Rouken Glen, Renfrewshire—30th May (Evening Excursion).

Aberfoyle, Perthshire—2nd June.

Gleniffer, Renfrewshire—9th June.

Joppa and Levenhall, Musselburgh, Midlothian—16th June.

Mark, Ardkinglas Estate, Argyleshire—23rd June.

Dunure and Heads of Ayr, Ayrshire—4th August.

Glen Culanach, Dumbartonshire—18th August.

Bardowie, Stirlingshire—1st September.

These were all successfully carried out, and were well and in some cases largely attended. The booklet of excursions was again issued, and it appears as if it were now to become a yearly publication, as it has been received with much favour by the members. The issue of the booklet has involved a considerable amount of extra trouble and expense, and the thanks of the Society are specially due to Mr. John Renwick for his exertions in this matter.

TRANSACTIONS.—The new part of the *Transactions* is now well advanced at press, and will, it is expected, be issued in the course of a month or two. It brings the proceedings and papers up to the end of Session 1904-1905, a state of matters which is entirely satisfactory, and it is hoped that in the future they will be issued with more regularity, each year's *Transactions* being issued at the beginning of the following Session.

DEATH OF MEMBERS.—The death of Mr. Murdoch towards the close of last Session came as a severe blow to the Society, for though he had not been able to come to any of the meetings, he still held office as editor of the *Transactions*, and was actually working at them up till the last moment. It will take the Society a long time to recover from his loss, as he devoted a very large part of his time to the furtherance of its interests, and though his work was more directly connected with the business of the Society rather than with actual geological investigation, yet it was none the less valuable, and, as in the case of those members who have done so much to advance the credit of the Society from a purely scientific aspect, we say, Who shall fill his shoes? Another serious loss to the Society was the death of Mr. Goodchild, which took place on February 21st of this

Digitized by Google

year, after a lingering illness. Mr. Goodchild did much for the Society, both by delivering popular lectures upon geological subjects and by the contribution of original papers, and his presence will be very much missed this Session. We have also to record the death of Captain Stewart, of Williamwood, who contributed to our *Transactions* in the year 1881 a valuable paper upon the limestones in the parishes of Cathcart and Eastwood, Renfrewshire. This paper may be said to form the foundation of our present knowledge of the stratigraphy of that district. Another old member of the Society who was removed by death last year was Mr. John Dansken. He served on the Council and was Vice-President of the Society, and for a long period he took a great interest in its work.

REPORT OF COUNCIL FOR 1906-1907.

Following the usual custom the Council beg to submit to the members an account of the work of the Society for the past Session from October, 1906, to September, 1907, the forty-ninth year of the Society's existence.

MEMBERSHIP.—The membership has fluctuated in the usual manner, and though we are not in a position to chronicle any great advance, yet it is satisfactory to know that the membership has not decreased. It is of great interest to note that an increasing number of students have been taking advantage of the Associate membership of the Society, and it is also still more worthy of note that quite a number of these Associates of former years have recently joined the Society as full ordinary members. In last year's Report the Council drew attention to the great desirability of carefully nursing this class of members, and they think that it is already beginning to show some signs of bearing fruit. The study of geology in Glasgow seems at the present moment to be in a better position than it has ever been, and the Council feel that though we are standing at the present moment with nearly fifty years of work behind us—work of the very highest order, as our *Transactions* show—and though nearly all the men who did this work have now passed from us, yet our present position is such as to inspire us with every confidence that the next fifty years ought to be able to show a record quite worthy of that which has now almost come to an end.

MEETINGS.—There were nine ordinary meetings of the Society during the past session, these being held from October to May. All of the meetings were well attended, and in some cases largely so. No special meetings have now been held for some years, and the Council think that this method of making the aims and objects of the Society more widely known might be adopted during the present Session.

PAPERS.—In all nineteen papers were read during the Session, most of them bearing upon important points in Scottish geology. Amongst these may be mentioned Dr. Peach's paper upon "The Geology and Scenery of Sutherlandshire and Ross-shire"; Mr. J. Renwick and Professor Gregory's

Digitized by Google

paper upon "The Loch Lomond Moraines"; Messrs. Carruthers and E. M. Anderson's paper upon "The Stratigraphy of the Arden Basin"; Mr. Dunlop's paper upon "The Mineral Seams Round Airdrie, and their Fossils"; Mr. Stark's paper upon "The Dykes in the Valley of Loch Long"; Messrs. Mort and Frew's paper upon "The Southern Highlands from Gourock"; and Mr. Macnair's paper upon "The Intrusive Dolerites of the Glasgow District."

SPECIMENS.—A large and exceedingly interesting number of specimens have been exhibited during the Session. These included specimens of minerals, rocks, and fossils. At one of the meetings an entire evening was devoted to the exhibition of specimens, and this proved so successful that it was determined to repeat the experiment upon a future occasion.

EXCURSIONS.—During the summer season there were eighteen excursions in all, three of these being evening excursions. Most of the excursions were well attended. A feature of the excursion syllabus for last Session was the series of excursions arranged for the purpose of studying the glacial phenomena of the Loch Lomond valley, the localities chosen being Loch Garabal, Glen Fruin, and Buchlyvie. These excursions were conducted by Professor Gregory and Mr. Renwick.

TRANSACTIONS.—It was resolved last year to try and issue a part of the *Transactions* every year, and to-night we are able to lay part 1 of vol. xiii. upon the table. This part also contains some papers of previous Sessions that were in arrear, and we are sorry to have to state that several important papers read last Session could not be printed in this part, as the authors did not supply the MS. in time for publication, though an extended period was given them. These papers, however, will be published in next year's part. We take this opportunity of impressing upon all authors of papers the desirability of having their MS. in the hands of the editors as soon after they have been read as possible.

FINANCES.—The finances of the Society will be reported on by your HON. Treasurer (Mr. E. Hall Wight), so that no more need be said here than that the Council are satisfied that they are in a sound condition.

LIBRARY.—A Report upon the present condition of the Library will be read to you by your Hon. Librarian (Mr. Wm. Sinclair).

EXCURSIONS FOR SEASON 1908.

To Kelvingrove Museum, on Saturday, 21st March—Mr. Peter Macnair, F.R.S.E., F.G.S., conductor. The party examined some of the recent additions to the geological collections, specially the new models, illustrating the geology of the Clyde Valley.

To Calderwood Glen, Lanarkshire, on Saturday, 4th April—Mr. A. Macintyre, F.S.A.A., conductor. The strata exposed in the bed of the Calder include the cementstone (Calderwood series), black shales, clayband, ironstone, sandstones, and limestones. The shale between the limestone is highly fossiliferous.

Digitized by Google

To Brodick Arran, on Monday, 20th April (the Spring Holiday)—Mr. James W. Reoch, conductor. This was a joint excursion with the Natural History Society of Glasgow. The objects of the excursion were to examine the shore section from Invercloy to Clauchlands Point, and the intrusive rocks of the Clauchland Hills. The rocks exposed along the shore are red sandstones and conglomerates of the Lower Triassic age, much faulted, and intersected by numerous dykes, and invaded by sills of felsite and pitchstone, including the well-known Corrygills pitchstone. Many ice-borne boulders of granite are strewed on the shore, of which the famous Corrygills boulder is estimated at over 200 tons weight. At Clauchlands Point the basic sill of the Clauchland Hills runs out to sea. The ridge of the hills was followed *via* Dun Fionn and Dun Dubh, and the return made thence to Brodick. Many of the broader geological features of the island were viewed from Dun Fionn.

To Motherwell, Lanarkshire, on Saturday, 2nd May—Mr. Robert W. Dron, C.E., conductor. This was a joint excursion with the Edinburgh Geological Society. The party examined the site of pre-glacial and inter-glacial course of the Tillon Burn, as exposed in the underground workings of the main coal seam at Coursington Colliery at a depth of 100 feet from the surface, and in sand quarries, and in the valley of the river Calder.

To Strathaven, Lanarkshire, on Saturday, 16th May—Mr. Robert Dunlop, conductor. The party first visited the old castle of Strathaven on the banks of the River Avon. There is no certain tradition as to its age, but it is generally supposed to have been built by Andrew, created first Lord Avondale in 1456. The party then examined some sections of limestone on the banks of the Avon, which are very fossiliferous, and where David Ure states he found plentiful specimens of *Spirifera Urei*. Good specimens are to be found of *Orthoceras*, *Bellerophon*, *Cypricardia*, *Dentalium*, &c., along with some of the more common fossils of the limestone, with also some fish remains and crustacea.

To Glen Ogle and Glen Beich, Perthshire, on Thursday, 21st May (Victoria Day)—Mr. Peter Macnair, F.R.S.E., F.G.S., Hon. Secretary, conductor. In Glen Ogle are numerous fine sections showing the Loch Tay Limestone folded along with its accompanying sill of epidiorite and overlaid by schistose grits, mica schists, and quartz schists. The character of the major and minor harmonic folding is also well displayed. The schists are penetrated by numerous dykes and sills of felsite, lamprophyre, and dolerite. The outcrop of the schists was traced along the north shore of Loch Earn into Glen Beich, where fine sections can be seen. In Glen Beich and Glen Ample the Loch Tay fault has brought the Ben Ledi grits against the Loch Tay Limestone and garnetiferous schists, and the position of the two glens has been largely determined by the fault. The glacial phenomena include the moraines in Glen Dochart, the moraine-dammed tarn at the head of Glen Ogle, and the rock basin of Loch Earn. Several landslips occur in Glen Ogle.

To Boylestone Quarry, Barrhead, on Wednesday, 27th May—Mr. Duncan Smith, conductor. At Boylestone Quarry there is exposed a

Digitized by Google

series of andesitic lava-flows of Lower Carboniferous age. The andesite contains many minerals, such as Prehnite, Analcite, Thomsonite, Saponite, Bowlingite, Olivine, Ferrite, &c., and in one part Metallic Copper is occasionally found, though as a mineral producer it is temporarily exhausted. The andesite is of a soft amygdaloidal nature.

To Lennoxtown and Craigenglen on Saturday, 30th May—Mr. James Anderson, conductor. (This excursion was the Jubilee commemoration of the first excursion of the Society, which was made to the same ground on the 29th May, 1858.) The route lay in nearly a direct line from Lennoxtown over the south hill of Campsie. The rock formations in the hill lie comparatively flat, and the same beds outcrop on both sides. The horizons are marked by the Hurlet and Campsie coal and alum shale and limestone, and the Hosie Limestone. Extensive ancient and modern workings have largely disturbed the regularity of the outcrops; but interesting exposures were seen in the bed of a stream on the north face of the hill, as well as in the Whapple Burn on the south slope. A spur from the Milton dolerite was crossed *en route*. The district is famous for fossils, indeed has been rendered classic by the publication of "The Geology of the Campsie District" by our late member, Dr. John Young, which can be consulted in the Society's *Transactions*, vol. i., part 1.

To Garscube Estate, on Wednesday, 10th June—Mr. John Renwick, conductor. The object of the excursion was to examine the Post-glacial channel of the river Kelvin in the Garscube policies, and the course of the river further down.

To the Lang Craigs, Dumbarton, on Saturday, 13th June—Mr. J. H. Thomson, Dumbarton, conductor. The Upper Old Red Sandstones of Dalreoch are overlaid by the Ballagan shales and dolomites as seen in Auchinreoch and Dumbuck Glens, and these are in turn overlaid by a great series of contemporaneous lava flows. The truncated edges of these are well exposed along the "Lang Craigs." An outlier on the hill behind Craigendoran indicates that they once extended much further west, but have been removed by denudation. Some of the flows are honeycombed with gas cavities in which various Zeolitic minerals have been crystallised from aqueous solutions, of which specimens may be obtained among the screes at the base of the Craigs.

To Giffnock Quarries, on Wednesday, 24th June—Mr. G. W. Tyrrell, A.R.C.Sc., conductor. The great quarries from which the famous Giffnock freestone is obtained were visited, and the underground galleries connecting the two main quarries on the east of the Kilmarnock road were passed through. In the old quarries to the west of the road the annelid beds and good local unconformities were seen.

To Carstairs, Lanarkshire, on Saturday, 27th June—Professor J. W. Gregory, D.Sc., F.R.S., conductor. The object of the excursion was to examine the structure and general distribution of the Kames of Carstairs which have been briefly described by Professor James Geikie in his "Great Ice Age," and also in the Memoirs of the Geological Survey of Scotland, Sheet 23. The first sections visited showed the very sandy type of the

Digitized by Google

Kames material, containing ice-scratched boulders and many water-washed pebbles on the inner side of the Kames line. The Kames were then crossed to the north of Carstairs village, and sections visited showing the less sandy and more morainic type. From the summit of the northern ridge, the view shows the contrast between the area within the Kames, covered with glacial debris, and the level peat swamps on the outer side of the Kames line.

To Lugar Water, Cumnock, and Cubb's Glen, Lugar, on Saturday, 4th July—Mr. Robert Boyle, B.Sc., conductor. The objects of the excursion were (1) to inspect the gorge of the Lugar, about 100 feet deep, near Old Cumnock Station, and the peneplain beyond; (2) to examine the intrusive igneous rocks of the Lugar district, and review the evidence adduced by the conductor in his paper in March last for their formation from the same magma, though presenting wide differences in chemical composition. All varieties and shades of rock are met with, from hornblende-peridotite to diabases and olivine-basalt; (3) to visit "Wallace's Cave," the site of the "Lugar Rocking Stone," and Cubb's Glen, one of the finest glens in Ayrshire. The Glenmore water has here cut a gorge in the igneous rock and fossiliferous limestones and shales, which is in some places 80 feet deep.

To Ballagan, Stirlingshire, on Saturday, 1st August—Mr. Joseph Sommerville, conductor. The chief object of this excursion was to examine the Cliff Section in the glen, belonging to the Lower Division of the Carboniferous Rocks, known as the "Ballagan Beds." These consist of a series of thin-bedded deposits, containing "upwards of 230 beds of limestone, sandstone, and marly shales, seen to lie, tier upon tier, in a slightly inclined position, and capped by massive beds of whitish sandstones and traps" ("Campsie," by the late Dr. John Young, F.G.S., *Transactions*, vol. i.). None of the limestone beds is above 1 foot thick; they are nodular and dolomitic, containing about 17 per cent. of magnesia. There are varieties of gypsum here—one impure, massive, reddish; another pure white fibrous; and a third yellowish, fibrous. Further up-stream a broad basalt dyke, probably miocene, runs east and west, with semi-circular sheets of 2 to 4 inches. In the centre of the Blane Valley, a conspicuous object, is Dunglass, a conical hill of basalt, with fine columnar structure.

To Finnich and Dhu Alt Glens, Stirlingshire, on Saturday, 5th September—Mr. William Sinclair, conductor. These very beautiful glens present fine examples of river erosion in the Red Sandstones, Calciferous series. Finnich Glen is one of the finest cañons in the west—quite unique in its way—and shows river caldrons high up in the cliffs.

To Kilsyth and Denny, Stirlingshire, on Monday, 28th September (Autumn Holiday)—Prof. J. W. Gregory, D.Sc., F.R.S., conductor. The four objects of the excursion were to examine—(1) the Carboniferous Rocks of the Kilsyth coalfield; (2) the Cementstones of the Calciferous Sandstones; (3) the section across the Kilsyth hills; and (4) the character

Digitized by Google

of the Carron valley. Leaving Kilsyth Station, sections in the Carboniferous Limestone series, with their intrusive dolerites, were examined. Beyond the great fault, which forms the southern boundary of the Kilsyth hills, the shales of the Cementstone group were followed. Working up the hills good exposures were seen of the lava-flows (mainly porphyrites) and volcanic ashes which form the dissected plateau of the Kilsyth hills. Descending northward, the Carron valley was reached where the river flows through a broad old valley with widespread glacial and river deposits. Below the alluvial plain the river plunges over in a picturesque waterfall into a narrow gorge, which continues across the rest of the porphyrite series. At Denny the Carboniferous Limestone series was again reached; it is cut through by a great mass of intrusive dolerite.

Digitized by Google

CASH ACCOUNT.

RECEIPTS.			EXPENDITURE.		
To Cash in Bank on Deposit,	£95 0 0		By Transactions—		
,, Cash in Treasurer's hands,	6 4 2		Printing and Publishing Vol. XII., Part 3, and for Reprints of Papers,	£50 3 0	
		£101 4 2	Postages, Typing, etc.,	2 8 6	
,, Subscriptions for current year (including 15 new Ordinary Members)—160 at 10/,		80 0 0			£52 11 6
,, Do. 1 at 7/6,		0 7 6	,, Library—		
,, Do. Arrears—9 at 10/,		4 10 0	New Books, Maps, and Magazines,	£11 10 6	
,, Life Membership Subscriptions—2 at £5 5s.,		10 10 0	Disbursements by Librarian,	0 10 0	
,, Associate Members' Subscriptions—13 at 2/6,		1 12 6			12 0 6
,, Handbooks and Catalogues sold,		2 14 9	,, Subscription to Marine Biological Association, 1907,		1 1 0
,, Interest on Funds,		9 0 9	,, ,, to Palæontographical Society, 1907,		1 1 0
			,, Writing Address on Vellum to the London Geological Society,		1 3 0
			,, Rent, Insurance, and Attendance,		13 10 0
			,, Printing and Postage of Circulars, Excursion Booklets, and Advertising,		19 6 0
			,, Lantern Expenses,		1 16 0
			,, Collector's Commission,		2 15 6
			,, Disbursements by Hon. Secretaries, Postages, Stationery, and Petty Expenses,		6 8 3
			,, Cash in Bank on Deposit,	£94 0 0	
			,, Cash in Treasurer's hands,	4 6 11	
					98 6 11
		£209 19 8			£209 19 8

STOCK ACCOUNT.

To Life Subscription Account,		£273 0 0	By Campbeltown Corporation Loan,	£270 0 0	
,, Capital Account,*		595 6 11	,, Cash in Bank and on hand,	98 6 11	
					£368 6 11
			,, Property—		
			Books in the Library,	£440 0 0	
			Furniture, Bookcases, and Microscope,	60 0 0	
					500 0 0
		£868 6 11			£868 6 11

* NOTE.—Subject to cost of publishing *Transactions*.

LIFE SUBSCRIPTION ACCOUNT.

Sept. 30, 1906—To Balance to Credit,	£273 0 0		October 1, 1906—By Balance,	£262 10 0
			Sept. 30, 1907—By Subscriptions during Year,	10 10 0
	£273 0 0			£273 0 0

GLASGOW, *7th November*, 1907.—Examined, compared with relative Vouchers and Securities, and found correct, the balance in Treasurer's hands being Four Pounds, Six Shillings and Eleven Pence.

JOSEPH SOMMERVILLE,
D. PEARSON, } *Auditors.*

Digitized by Google

Digitized by Google

TRANSACTIONS

OF THE

GEOLOGICAL SOCIETY OF GLASGOW.

No. XXII.—A New Occurrence of Picrite in the Ballantrae District and its Associated Rocks. By G. W. Tyrrell, A.R.C.Sc., Assistant in Geological Department, Glasgow University.

[Read 12th November, 1908.]

I. *Introduction.*

The rocks described in this paper occur on Littleton Hill, 3½ miles N.E. of Ballantrae. This hill is the western prolongation of Balhamie Hill, where the famous bronzite-serpentine is obtained. On Sh. 7 of the Geological Survey of Scotland Littleton Hill is mapped as four small intrusions of basic rocks piercing the great mass of serpentine stretching from the shore N. of Ballantrae in a north-easterly direction to Millenderdale. The igneous rocks of this district are regarded as the plutonic phase of the Arenig vulcanicity. Their débris is conspicuous in the conglomerates and grits of the immediately succeeding Llandeilo and Caradoc beds.

The field relations of the "intrusions" of Littleton Hill are very obscure. Small isolated exposures occur at several places on the hill, rarely presenting continuous sections of more than 10-15 feet in length; and the junction with serpentine is not seen. The four small masses mapped by the Geological Survey form distinct knolls, diversifying the otherwise rather featureless contours of the hill.

These exposures consist of a fine grained grey to black rock, occasionally sparingly porphyritic with felspar, which in hand specimens would be called dolerite or basalt. A more or less

Digitized by Google

parallel, banded or schistose structure, is seen on the north face of the hill, near the 500′ contour; and about 200 yards N.W. of the summit,[1] there occurs a small exposure of a dense black rock, very tough and resistant to the hammer. A fresh fracture shows glistening flakes of dark mica. On sectioning, this rock is seen to be composed essentially of hornblende and biotite, with subordinate olivine, felspar, and iron ores. Petrographically it is a hornblende-mica-picrite. Its relations to the less basic rocks of the hill cannot be traced in the field, but the petrographical evidence renders it probable that it is a local ultrabasic modification of these rocks.

II. *Microscopic Characters of the Picrite.*

The minerals present are hornblende, biotite, alteration products of olivine and felspar, magnetite, and apatite, in order of abundance.

The hornblende occurs mainly in dense aggregates of small granules of a deep reddish brown colour. Occasionally there are larger crystals of a pale, bleached yellow tint, crowded with magnetite dust, and passing on the margins into the granulitic condition, which is free from separated magnetite. The colour of the granulitic hornblende is therefore probably due to the absorption of magnetite. The pleochroism is as follows:—X, pale yellow; Y, brownish green; Z, deep reddish brown.

The large bleached plates of hornblende are sometimes seen in polarised light to break up into small, vaguely-outlined, rounded areas, which seem to foreshadow the granulitic condition.

Almost as abundant as hornblende is biotite of a peculiar and intense pleochroism. The scheme is as follows:—X, very pale yellow; Y and Z, reddish brown to a peculiar purplish red (beetroot colour). From the optical tests possible in such small sections it appears that the mineral is an anomite, similar to the deep red anomites peculiar to some soda-rich rocks.

The hornblende and mica each tend to aggregate in certain areas, so that the coloured mineral in one field may be almost entirely hornblende, in another mica. There is a tendency

[1] *See* Ord. Survey, 6-in. quarter sheet, Ayrshire, 61 S.W.

Digitized by Google

for the large plates of hornblende to enclose the small flakes of biotite.

Some small, rounded areas are occupied by a chloritic mineral, highly pleochroic in shades of yellow and green. It frequently has a strong cleavage and bent lamellæ, and is probably a ferriferous variety of chlorite. There is difficulty in regarding it as derived from hornblende or mica, as both are perfectly fresh in the rock. It probably represents a vanished pyroxene.

Olivine is represented by roughly hexagonal areas of spongy iron ore surrounded and enclosed in a greenish serpentinous substance. Magnetite occurs primarily in small ragged crystals; also as dust, and as a grating-like skeletal aggregate in the interior of the larger plates of hornblende.

Finally, there are some areas of a whitish or yellowish semi-opaque, apparently crypto-crystalline substance, which gives rather bright polarisation tints. These are thoroughly epidotised felspars, as in a few places the mineral clears a little, so that albite twinning, in one case crossed by pericline, is still to be seen. They contain small, dark, indeterminate inclusions, at one place arranged in a swirl or eddy-shaped form.

The specific gravity of this rock is 3·03. It differs somewhat from other picrites in the predominance of hornblende and biotite over olivine and pyroxene. The large, bleached plates of hornblende above described have probably been derived from original pyroxene.

III. *The Granulitic Hornblende Diorites.*

These are dense, fine-grained rocks consisting of a granulitic aggregate of hornblende, felspar, mica, and perhaps quartz, with a little magnetite.

In a specimen from above the 500′ contour, a little W. of the line of shooting-butts on the south face of the hill,[2] the hornblende and felspar are aggregated into little elongated areas, which have a parallel arrangement. The hornblende shows precisely the same characters as the granulitic hornblende

[2] *cf.* Silurian Rocks of Britain. Vol. i. Scotland (1899). *Mem. Geol. Sur.*, p. 477-479.

Digitized by Google

of the picrite, but is not found in large plates. The felspar is clear, fresh, granular, and, for the most part, untwinned. The majority of the granules have a higher refractive index than Canada balsam, as determined by the Becke method, but a few have a lower index. The latter are probably orthoclase or albite. The twinning, when visible, is too minute to give satisfactory extinction determinations. Quartz may occur among the water-clear granules of the ground mass. Occasionally the felspars contain numerous small, yellowish-green granules of epidote. Biotite occurs very sparsely as compared with the picrite. Magnetite occurs in minute specks. The specific gravity of the rock is 2·94.

On the S.W. slope of Littleton Hill, about ½ mile north of Bougang Farmhouse,[3] occurs a slightly different variety. It is composed of granulitic hornblende and plagioclase, as in the rock described above, but there are also phenocrysts of plagioclase and pyroxene. The granulitic felspar is water-clear, usually untwinned, but occasionally with fine, closely-set twin lamellæ, giving a maximum extinction angle of 15 degs. The refractive index is higher than that of Canada balsam, and the mineral therefore belongs to andesine.

The phenocrysts of plagioclase range up to 3 mm. in diameter. They are sometimes bent, or even broken across. The twin lamellæ are also frequently curved, and, locally, a secondary set of twinning planes have been developed. The crystals are usually quite fresh, and only slightly zonal—occasionally, however, they are somewhat epidotised. In one or two cases they have been thoroughly granulitised, and nearly all the phenocrysts show strings and patches of granulitic felspar. The maximum extinction angle in symmetrically cut albite-twinned crystals is 31 degs., corresponding to a composition Ab_2An_3—a medium labradorite.

In one part of the slide there are two idiomorphic phenocrysts of pyroxene, the larger of which is 1·3 mm. in diameter. The latter is nearly a basal section, showing (110) well, but (010) and (100) very poorly developed. It is penetrated by little strings of granulitic hornblende, and is bordered by a zone of these granules, especially where it abuts on a felspar. A closely-set diallagic striation parallel to a pinacoid is still to

[3] *cf.* Silurian Rocks of Britain. Vol. i. Scotland (1899). *Mem. Geol. Sur.*, p. 479.

Digitized by Google

be seen, and there is a distinct bronzy sheen if the mineral be viewed in reflected light. Reddish brown biotite occurs in moderate amount, and magnetite in small grains sparsely but uniformly distributed. The specific gravity of the rock is 2·85.

IV. *Conclusions.*

The granulitic hornblende-felspar rocks of Littleton Hill have been briefly described by Dr. Teall in the Geological Survey Memoir on the Silurian Rocks of Scotland (1899).[4] He considers the granulitic structure entirely secondary, and makes the guarded suggestion that it is due to contact metamorphism. He remarks, "If they represent an altered phase of the porphyritic diabase lavas, then the matrix must have been entirely recrystallised." In the last volume of these *Transactions* Mr. F. Mort[5] has described the rocks of Littleton Hill, especially from the point of view of their passage into true schist. He obtained a true olivine dolerite near the summit, still retaining ophitic structure between augite and felspars, and showed by a graduated series of specimens that the augite breaks up into the granulitic brown hornblende, the ophitic structure disappears, and the rock finally takes on the structure of a true hornblende schist. Only one of my own slides shows any recognisable pyroxene, and that in very small quantity. I have therefore called the rocks diorites, although they have certainly been derived from pyroxene-plagioclase rocks. Mr. Mort describes and figures phenocrysts of fresh olivine with well-marked reaction rims in the rock from the S.W. flank of Littleton Hill.

These rocks bear little resemblance to the ordinary types of basic igneous intrusions. Many features connected with them suggest that they are the products of metamorphism. The granulitic structure, the freshness of the constituents, and the peculiar nature of the coloured minerals suggest that the agent involved is heat. Many instances of the contact metamorphism of igneous rocks have now been described. The augite-andesites on the west side of the Shap granite, according to Mr. Harker,[6] have been entirely recrystallised by contact-metamorphism, the ground mass becoming a fine textured

[4] Pp. 478-480.

[5] Vol. xiii. (1908), pt. ii., pp. 187-190. I am indebted to Mr. Mort for the kind loan of his slides.

[6] *Q.J.G.S.* Vol. xlvii. (1891), p. 296; vol. xlix. (1893), p. 362.

Digitized by Google

mosaic of clear granules, whilst the felspar phenocrysts have been replaced by granules of new felspar substance. Diabases metamorphosed by a granitic intrusion in Cornwall had had their augites altered to a greenish hornblende, which in the neighbourhood of iron ore is sometimes brown.[7] This is paralleled by the granulitic reddish-brown hornblende of the picrite and diorite described in this paper, which clearly owes its colour to the resorption of magnetite dust. Although these rocks have undergone some degree of strain, as indicated by bent lamellæ, secondary twinning, and faulted crystals among the plagioclase phenocrysts, yet the survival of olivine and the retention of ophitic structure, as described by Mr. Mort, indicate that this dynamic action cannot have been severe, and still less can the peculiar appearances in these rocks be ascribed to it.

Further examination of the rocks of Littleton Hill does not support the idea of their derivation from the porphyritic diabase lavas of this district. The presence of phenocrysts of plagioclase, olivine, and diallage, with traces of ophitic structure, indicates that their true affinities are with rocks similar to the intrusive dolerites and gabbros so common in the Ballantrae district. The augite has been transformed, first into a pale, uralitic hornblende, then by further metamorphism and resorption of magnetite into the granulitic red-brown variety. The comparative scarcity of magnetite may perhaps be explained in this way. The felspar has been recrystallised with the formation of a water-clear mosaic. The survival of olivine is a puzzling phenomenon. I have not been able to obtain any data as to the behaviour of olivine during contact-metamorphism. There is no reason, however, to believe that a mineral of the simple composition of olivine would be broken up. Perhaps the reaction rims described by Mr. Mort represent the utmost effect of contact-metamorphism on this mineral.

The local modification into a picrite on the north side of the hill is explicable on the hypothesis that the original rock was a basic intrusion similar to those common in the district, for these tend to pass into ultrabasic types.[8] The diabase-porphyrite lavas, on the other hand, are essentially felspathic rocks of very uniform composition, with only a small content

[7] Allport. *Q.J.G.S.*, vol. xxxii. (1876), p. 420.

[8] *Mem.* on Silurian Rocks of Scotland (1899), p. 469-470.

Digitized by Google

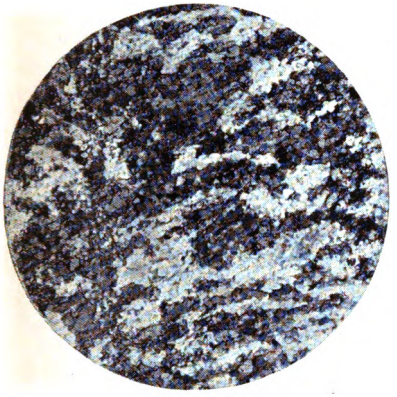


Fig. 1.

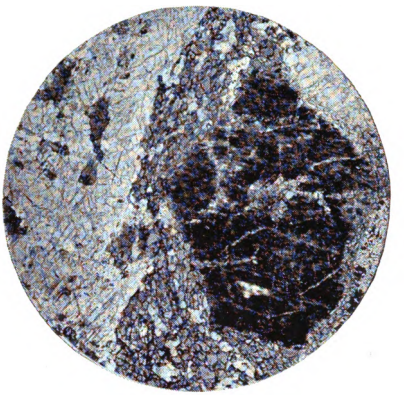


Fig. 2.

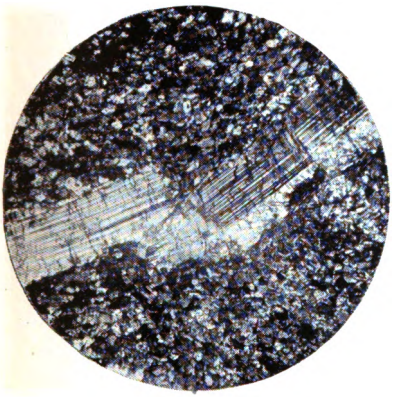


Fig. 3.

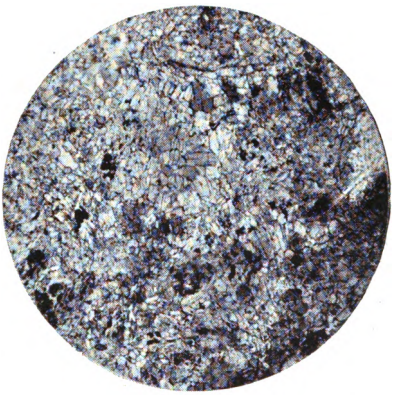


Fig. 4.

Micro-photographs of Rocks from the Ballantrae District.

Digitized by Google

Digitized by Google

of femic minerals. Moreover, they are exceedingly amygdaloidal, and Mr. Harker has shown, in the case of basic lavas metamorphosed by plutonic masses in Skye, that the amygdaloidal structure is very persistent, the amygdules appearing as rounded, eye-like structures even when the rock has been entirely recrystallised.[9] No such appearances have been detected in the rocks of Littleton Hill.

If the foregoing inferences be sound, then, instead of being intrusive, the rocks of Littleton Hill must be regarded as relics of an older mass of dolerite or gabbro enveloped by the later serpentine. The dynamic effects noted above may perhaps be regarded as due to the disruptive action of the serpentine intrusion. Many of the dolerites and gabbros of the district are certainly later than the serpentine, but these do not show the abnormal appearances of the Littleton Hill rocks. Rocks having the same characters have been recorded at several other localities in this district,[10] and it is permissible to assume that they have had a similar origin.

EXPLANATION OF PLATE.

Fig. 1.—Granulitic hornblende-mica diorite, Crags near shooting-butts, S. side of Littleton Hill. Ord. light, × 24.
A granulitic aggregate of brown hornblende and biotite, with water-clear plagioclase. The coloured minerals are not distinguishable from each other in the photograph. The field shows the separation of hornblende and biotite into long narrow streaks, alternating with similar streaks of plagioclase. This is the beginning of true schistose structure.

Fig. 2.—Granulitic hornblende-mica diorite, porphyritic variety, S.W. flank of Littleton Hill. Ord. light, × 24.
Shows phenocrysts of diallagic pyroxene and plagioclase in groundmass consisting of brown hornblende and biotite, with water-clear plagioclase. The pyroxene shows very close lamellation parallel to one of the pinacoids, and is surrounded by a zone of brown hornblende, by which it is also penetrated in streaks and patches. The porphyritic felspar is broken up into a granular aggregate, and is also penetrated by strings and patches of hornblende.

[9] Tert. Ign. Rocks of Skye (1904), pp. 52, 115, 116.
[10] *Mem.* on Silurian Rocks of Scotland (1899), pp. 477-479; 482.

Digitized by Google

Fig. 3.—Same slide as Fig. 2, but different field. Polarised light, × 24.
Shows a broken crystal of plagioclase in a granulitic groundmass of hornblende, mica, and plagioclase.

Fig. 4. — Hornblende-mica picrite, N. side of Littleton Hill. Ord. light, × 24.
The field shown consists almost entirely of brown hornblende and mica. One or two of the larger plates of pale bleached hornblende are seen in the top left-hand corner of the field. Olivine, represented by serpentinous alteration products, is seen as clouded areas at the bottom left-hand and top right-hand corners. Decomposed felspar occurs on the extreme left of the field.

Digitized by Google

No. XXIII.—Notes on "Eyed" Coal from Gateside Colliery, Cambuslang. By Peter Macnair, F.R.S.E., F.G.S.

[Read 11th February, 1909.]

About a year ago Mr. James Kirkpatrick brought to Kelvingrove Museum for my examination a number of specimens of "eenie" or eyed coal. They had been found by him at Gateside Colliery, Cambuslang. Mr. Kirkpatrick informed me at that time that he intended publishing a description of this somewhat remarkable coal, and only last night, along with Mr. C. T. Clough, he read a paper before the Mining Institute of Scotland dealing with similar specimens. I had the privilege of hearing this paper, which has since been published.[1] It gives a very interesting account of all that is known regarding the peculiar structures shown in this coal. As there are, however, several points not touched upon by the author of this paper, I have ventured to lay the following notes upon the same subject before you.

The eyed coal from Gateside Colliery occurs in flattened lenticles which may reach 5 or 6 feet in length, and have a width of 8 or 9 inches across their broadest parts. They occur in a bed of fireclay which lies between the Ell coal below and the Crow coal above.

The lenticles lie parallel to the bedding planes of the strata, and it is quite clear that they are simply the carbonised remains of prostrate tree stems that have become embedded in the fireclay. No organic structure is shown in the coal, but the outside of the lenticle shows a series of parallel ribbings which are undoubtedly part of the original structure of the tree. The cross sections of the lenticles present an elliptical shape. Originally the transverse sections would have been approximately circular, but they have been compressed into their present shape by the pressure of the superincumbent strata.

The coal of which the lenticles are formed is of the brittle, glassy character so often found encrusting the sandstone casts

[1] *Transactions of the Institution of Mining Engineers*, 1909.

Digitized by Google

of carboniferous tree stems. It will presently be seen that this kind of coal seems to be particularly suited for the development of the eyed structures which it contains. The following analysis of the coal has been kindly made for me by Mr. John S. G. Primrose, of the Metallurgical Department, Glasgow Technical College:—

Moisture,	8·750	per cent.
Volatile Matter,	31·610	,,
Ash,	3·975	,,
Fixed Carbon,	55·665	,,
	100·000	per cent.

The vertical section given beneath was supplied to me by Mr. Kirkpatrick. It shows the different strata that are associated with the eyed coal. On the top is shown the "crow coal," immediately below this is the fireclay containing the lenticles of "eenie coal," while below the fireclay comes the different bands of coal which together make up what is known as the ell coal. See Fig. 1.

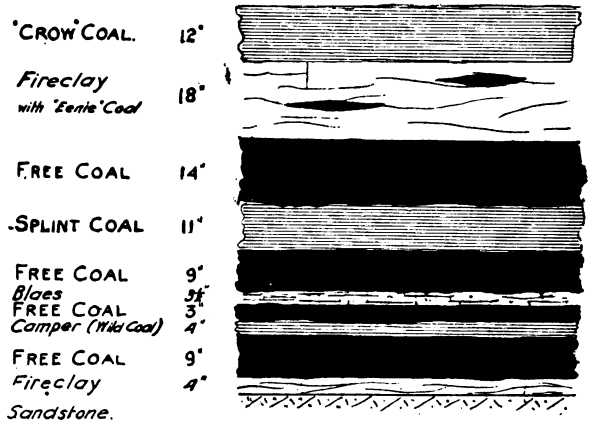


Fig. 1.

Turning now to a consideration of the eyes, we find that they are all arranged in planes at right angles to the longer axis of the lenticle, and, of course, also at right angles to the bedding planes of the strata. In shape most of them are more or less perfect circles, while a few are elliptical. They vary in size from that of a pin head up to 2 inches in diameter. They also

Digitized by Google

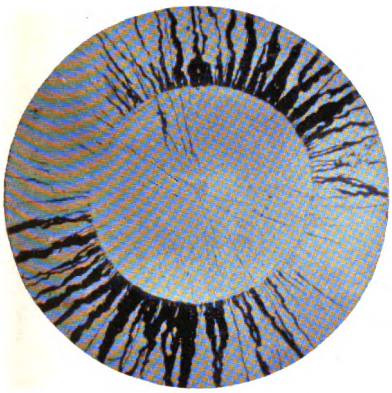


Fig. 1. × 25.

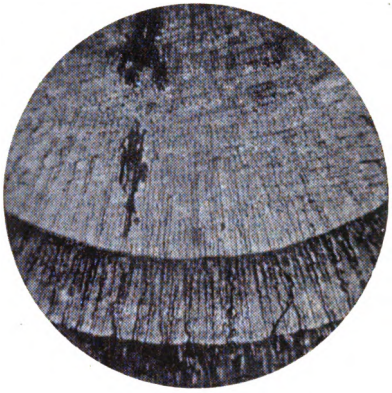


Fig. 2. × 25.

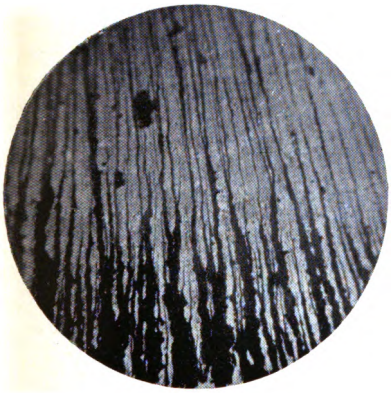


Fig. 3. × 35.

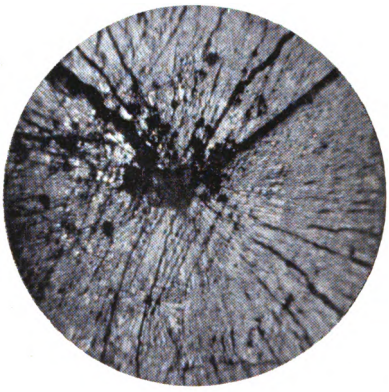


Fig. 4. × 25.

Discs of Gypsum from "Eyed" Coal, Gateside Colliery, Cambuslang.

From Photos. by Peter Macnair.

Digitized by Google

Digitized by Google

occur in different degrees of development. In some parts of the coal they appear in a very incipient stage of formation, while in others they seem to have reached their utmost stage of perfection.

The less perfectly developed eyes simply consist of a saucer-like depression, from which radiate a series of cracks. In the more perfectly developed forms the central saucer-shaped depression is surrounded by circular depressions which vary both in width and depth, the hollows being marked by definite and fairly continuous circular ridges. The less perfectly developed structures, then, consist simply of a series of radial lines; the more perfect forms have, in addition to the radial lines, a series of concentric circles, which appear to divide off the eye into a number of concentric bands. This description refers to the concave side of the eye, the convex side exhibiting exactly the reverse phenomena.

In Plate XVIII., Fig. 2, there is shown a part of one of the lenticles of coal in which several well-developed eyes can be seen. They exhibit all the features that have just been described. Thus, in the right of the specimen is shown an eye which is still partly covered with a thin film of gypsum. The character of these films will be presently described. This eye is over an inch and a half in diameter, and consists of a single depressed area in the centre measuring $\frac{3}{4}$ of an inch in diameter. From this central depression diverge the innumerable fine radiating cracks which have been described. To the left and below this large eye can be seen two small eyes which do not measure more than $\frac{3}{4}$ of an inch in diameter. The lowest of these on the margin of the photograph is covered by one of the discs of gypsum. In the centre of the photograph are shown two eyes which, beside the central depression, have, in addition, two concentrically depressed areas. These may be taken as examples of the more perfectly developed forms.

One of the most interesting features in the eyed coal is the presence of thin films of different mineral substances within the hollows of the conchoidal fractures. These include calcite, galena iron pyrites, a ferriferous carbonate, and a substance which I take to be gypsum. Calcite occurs somewhat sparingly. When examined under crossed nicols in convergent light it is seen

Digitized by Google

that the calcite film consists of numerous crystals, which show in many cases a perfectly symmetrical interference figure. From this I conclude that the film is made up of crystals which are largely combinations of the basal plane (111) and the hexagonal prism (211). In some parts of the calcite film the crystals are distinctly idiomorphic, and these faces are well developed, the crystal presenting a distinct hexagonal outline. In a few instances they are terminated with a rhombohedron, the exact form of which I have been unable to determine, as the crystals are exceedingly minute. They seem, however, to be the obtuse rhombohedron (110). The facility with which the thin discs of calcite can be removed from the coal, and the ease with which they can be mounted, makes them particularly suitable objects for demonstrating the principal physical and optical properties of that mineral, as they show some of its characteristic forms, cleavage, the uniaxial figure, and the character of the double refraction. Occasionally calcite and gypsum are to be met with in the same disc, when they present certain peculiar features which will be presently described.

Of all the different mineral substances filling up the conchoidal fractures in the coal the mineral which I have provisionally referred to, gypsum, is perhaps the most abundant. In my first examination of this substance, though only a small quantity of it was available, I came to the conclusion that it must be gypsum, for the following reasons:—First, it has a hardness of about 2, as it can be easily scratched by calcite and by the thumb nail; second, when the films were heated before the blowpipe they became white and opaque, behaving in exactly the same manner as gypsum; third, in the closed tube it gave off distinct traces of water; fourth, when examined in the microscope under crossed nicols they exhibited all the optical characters of that mineral.

Since making the preliminary examination of the mineral Mr. S. G. Primrose has kindly made an examination of it for me, with the following result:—He finds that the coal itself yields about 2 per cent. of sulphur. He also considers that, from the amount of sulphur present in the "een" themselves, they must consist of something more than $CaSo_4$. According to the empirical formulæ, the amount got only yields about 70 per cent. of that substance. He also adds that there seems

Digitized by Google

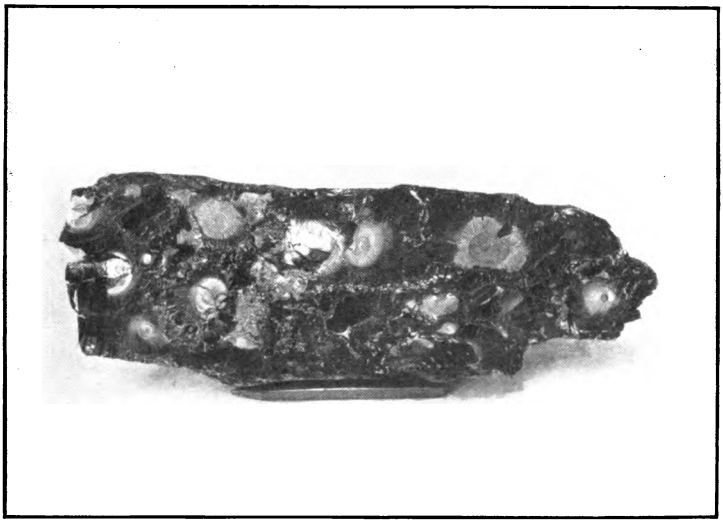


Fig. 1.

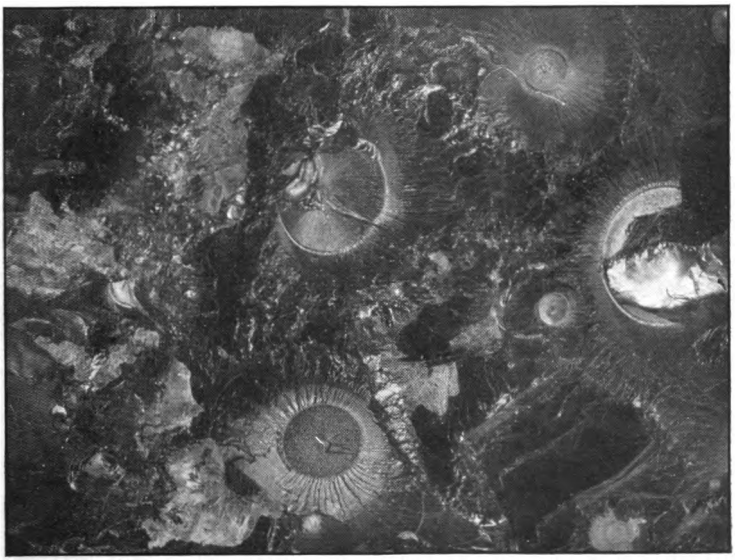


Fig. 2.

"Eyed" Coal from Gateside Colliery, Cambuslang.

From Photos. by J. W. Reoch.

Digitized by Google

Digitized by Google

to be present some small quantity of an aluminium salt. When these discs are examined under the microscope they are seen to contain large quantities of pyrites, galena, and coaly matter in such a fine state of admixture with the gypsum that it would be impossible to separate the pure gypsum.

When examined under crossed nicols in the microscope the discs of gypsum are seen to exhibit a beautifully developed radial structure, such as is to be found in wavellite when it occurs lining fissures in rocks. This structure is due to the arrangement of the crystals, so that their longer axes all radiate from a centre like the spokes of a wheel, a structure characteristic of crystals which show a tendency to a prismatic or acicular habit. When viewed under the microscope this divergent, fibrous structure shows a black cross between crossed nicols, the arms of which are parallel to the short diagonals of the two nicols.

Even the most cursory examination of these discs of gypsum is sufficient to show that their structure has largely been determined by the character of the eye of conchoidal fracture within which they have been formed. In the majority of cases the centre of the discs is also the centre of such a radial arrangement of the gypsum crystals. As a rule, the thin disc or film consists partly of acicular crystals arranged in this radial manner and partly of grains showing a fine cryptocrystalline structure. The radial arrangement so frequent in the centre of the disc is well shown in Fig. 4, Plate XVII. A smaller disc is also shown immediately below the large central one.

I pass now to a consideration of the manner in which this eyed coal has been formed, and in the first place I may briefly refer to some of the opinions that have been entertained regarding its origin. These have been treated in some detail in Messrs. Clough and Kirkpatrick's paper, to which the reader is referred. In our own *Transactions* I find that Mr. John Dougan exhibited in 1886 a specimen of coal from Langloan, "showing a peculiar collapsed spheroidal structure." This I take to have been of the same character as the specimens under discussion. No attempt, however, is made to explain the structures in the coal; but I have been able to gather from some of the members that when the specimen was exhibited it was considered that the structure was due to the collapse of spheres when the coal

Digitized by Google

was in a plastic condition. It has also been suggested that the eyed structure might be due to contact with an igneous intrusion, but in the Gateside district there is no evidence to show that the structures are due to contact with an igneous rock. A small dyke of white trap has been met with in the workings, but Messrs. Clough and Kirkpatrick have pointed out that the eyed structure is much more perfectly developed at a distance from the dyke than it is in its immediate neighbourhood. Again, similar structures have been found in districts like the Yorkshire coalfield, where no igneous rocks are known to occur.

There can, I think, be no doubt that the structures have been produced by pressure, and are similar in origin to the percussion bulbs found in glass, obsidian, pitch, and flint. It is well known that when these substances are struck with a sharp blow they yield a structure analogous in every respect to that seen in the eyed coal. Similar structures can also be seen in a more or less perfect state of development in flint and obsidian, which has been fabricated with arrowheads or other implements during recent or prehistoric times. It is also well known that those who manufacture flint implements for sale at such centres as the Giant's Causeway produce their implements not by distinct blows, but by the continued pressure of a small flake of dolerite. It is important to note, however, that in implements of flint or obsidian that have been flaked in this manner the bulb of percussion is never a complete circle, but only the segment of a circle with the point of pressure as its centre, the direction of the pressure being in the same plane as the percussion bulb. It seems that the almost perfect symmetry of the eyes in the coal would require that the pressure should have taken place at right angles to the structures themselves.

Since exhibiting the coal from Cambuslang I have received a number of interesting specimens of a somewhat similar character from Mr. Shanks, of Messrs. Shaw & M'Innes, Firhill Iron Works. They are from Cadder Pit, belonging to the Carron Company, which is situated on the banks of the Forth and Clyde Canal, near Cadder. One point is made exceedingly clear by these specimens, namely, that the eyed structure has been produced by pressure acting at right angles to the bedding planes of the coal. The coal in which the structures are met

Digitized by Google

with is of the cannel type, and shows well-defined stratification planes. The eyes are on a much larger scale, though not anything like so perfectly developed as those from Gateside. They stand at right angles to the bedding planes. One of the eyes, if complete, would measure over 8 inches in diameter.

The Cadder specimens, like those from Gateside, have been filled in with thin films of calcite and pyrites. The latter mineral is often beautifully crystallised into cubes, octahedrons, and pentagonal dodecahedrons. In some cases it exhibits a radial arrangement of the crystals of a similar character to that seen in the gypsum films of the Gateside specimens. It is worthy of note that the cannel coal at Cadder, like the Gateside lenticles, lies enclosed in a bed of ironstone.

As regards the origin of the different substances found in the thin discs between the "een," there can, I think, be no doubt that they have been deposited within the conchoidal fractures at some period after the development of the fractures. Pyrites and calcite are common minerals in association with coal. Gypsum is also of frequent occurrence. From the manner in which the pyrites is associated with the gypsum, it seems as if pyrites was the original substance in the fractures. That by oxidation sulphuric acid was formed from the pyrites, and this, acting on a calcium compound, produced the coating of calcium sulphate or gypsum which has replaced the iron pyrites. I am indebted to Mr. J. W. Reoch for the photographs shown in Plate XVIII.

EXPLANATION OF PLATES.

Plate XVIII., Fig. 1.—Section of tree stem consisting entirely of coal and showing eyed structure, from Gateside Colliery, Cambuslang.

Plate XVIII., Fig. 2.—Portion of Fig. 1 enlarged to natural size.

Plate XVII., Fig. 1.—Disc of Gypsum showing a centre composed of cryptocrystalline gypsum surrounded by rays of carbonaceous material, × 25 times ordinary light.

Fig. 2.—Part of a Disc of Gypsum showing segments of two rings with closely packed rays of carbonaceous material, × 25 times ordinary light.

Fig. 3.—Disc of Gypsum showing structure in detail, × 35 times ordinary light.

Fig. 4.—Disc of Gypsum showing radial arrangement of the crystals × 25 crossed nicols.

Digitized by Google

No. XXIV.—The Classification of the Post-Carboniferous Intrusive Igneous Rocks of the West of Scotland.

By G. W. Tyrrell, A.R.C.Sc., Assistant in Geology, Glasgow University.

[Read 11th March, 1909.]

I. Introduction.

No one studying the geological maps of Scotland, on whatever scale, can fail to be impressed by the enormous amount of igneous activity they disclose in the geological history of that country. The broad areas of pink or brown, indicating great lava plateaux, and the splashes and stripes of crimson, indicating intrusive rocks, are literally everywhere. Not only are the igneous rocks widely distributed in space, but also in time. Practically every formation up to the Permian supplies its quota. In the Archæan we have the great foundation of gneiss, with its inextricable tangle of acid and basic igneous rocks. The Dalradian schists and gneisses of the Grampians are everywhere penetrated by igneous masses now largely metamorphosed to massive epidiorites and hornblende schists. The Cambrian of the north-west Highlands contains an interesting complex of highly alkaline rocks, including borolanite and several other rare types. The Ordovician, Devonian, Carboniferous, and Permian in Scotland each exhibit a great series of extrusive and intrusive igneous rocks. Finally, after a long period of quiescence in the Mesozoic, an enormous outburst of igneous activity in the Tertiary gave rise to the great lava plateaux of the Western Isles.

This richness in material makes Scotland a petrographer's paradise. The amount of work that has been done, however, in spite of the labours of Zirkel, Allport, Judd, Geikie, Teall, Harker and others, is very little in comparison with the great amount that still remains for petrographers to do. "No adequate investigation," says Sir A. Geikie, referring to the Carboniferous plateau eruptions, "has yet been made of the chemical and microscopic characters of these various rocks, regarded as a great volcanic series belonging to a definite

Digitized by Google

geological age, though many of the individual rocks and the petrography of different districts have been more or less fully described."[1] The same remark is applicable to the igneous rocks of many of the other formations, although in regard to some we are fortunate in possessing memoirs like that of Mr. Harker on "The Tertiary Igneous Rocks of Skye."

The district about Glasgow and the West of Scotland generally is exceptionally favourable to the study of igneous petrology. The great lava plateaux of the Campsie, Kilpatrick, and Renfrewshire Hills are in close proximity. The Old Red Sandstone and Permian igneous rocks of Ayrshire, and the numerous, as yet unclassified sills and dykes, are practically virgin ground. In addition, there are the Tertiary volcanics of the Western Isles, and that favoured island of perennial petrological interest, Arran.

The ages of various groups of igneous rocks in Scotland are well defined up to the Carboniferous by their association with sediments of definite age. This is, of course, especially true of interbedded lavas. For intrusive rocks, however, the evidence may not be quite so conclusive. Nevertheless, it has been found possible, by means of several converging lines of evidence, to ascertain the place in time of several groups of intrusive rocks. A difficulty arises, however, when we come to intrusions piercing the younger Carboniferous rocks on account of the absence or fragmentary condition of all younger sediments. The lavas intercalated with those small patches of red sandstone overlying the Coal Measures in Ayrshire may be regarded with some probability as Permian. There remain, however, a great number of *intrusive* masses, later than the Carboniferous, whose exact age is still very uncertain. It is with these rocks that it is proposed to deal in this paper. It is hoped to show by the petrographical evidence that they fall into several well-defined groups, the respective ages of which may be determined with some degree of precision.

Although the use of age distinctions in the general classification of igneous rocks has fallen into disrepute, mainly owing to the criticisms of British petrologists, it is well to remember that, in strictly circumscribed areas, the igneous rocks of a

[1] "Ancient Volcanoes of Great Britain" (1897). Vol. i., p. 377.

Digitized by Google

particular age are often characterised by a distinct petrological facies. To take a particular case: while it is impossible to maintain that there is a world-wide classificatory difference between Carboniferous and Tertiary dolerites, yet within limited areas such differences may frequently be recognised, and are often very constant and peculiar. Moreover, when minuter petrological and chemical features are taken into account, these distinctions become much sharper, and constant differences may also be recognised between the igneous rocks of different parts of the same formation. While this principle is used in this paper, it is not maintained that single rock specimens can be assigned to their respective age groups on petrological examination alone. For example, it may not be possible to distinguish between the marginal facies of a late Palæozoic quartz-diabase sill and some of the Tertiary dykes, or between the analcite-free facies of the teschenite group and some of the coarser ophitic Tertiary dolerites. But if a small, representative suite of specimens from any particular occurrence is available, then there should not be much difficulty in assigning it to its particular age group.

II. Literature.

It will be necessary here to review, as briefly as possible, some of the work already done in the petrology of the West of Scotland. These notices will be strictly confined to the range indicated by the title of this paper, namely, to the post-carboniferous intrusive igneous rocks of the West of Scotland. On account of the enormous increase of precision in classification afforded by the introduction of the microscope into petrology, it will be unnecessary here to refer to the many valuable memoirs of pre-microscopic days. Accordingly, our first reference is to be found in the classic pioneer paper of the late Dr. Sorby, "On the Microstructure of Crystals." In this paper the pitchstone of Arran is described at some length, mainly with regard to the enclosures and cavities in the porphyritic crystals.[2] Whilst petrological study was somewhat neglected in Britain during the ensuing years, it was taken up enthusiastically by Continental geologists, one of whom, Ferdinand Zirkel, paid

[2] *Q.J.G.S.*, vol. xiv. (1858), p. 476.

Digitized by Google

especial attention to the rocks of Western Scotland. He described some of the Arran pitchstones in his "Microscopische Gesteinsstudien,"[3] but his most important contribution is to be found in his "Geologische Skizzen von der Westküste Schottlands."[4] Herein is described very fully the granites, "traps," and pitchstones of Arran, and many other of the igneous rocks within our range occurring in Mull, Iona, Staffa, and Skye. In the next year, 1872, Samuel Allport contributed two papers to the *Geological Magazine* on the pitchstones and felsites of Arran.[5] These were followed in 1874 by his great paper on "The Microscopic Structure of British Carboniferous Dolerites," in which many Western Scottish rocks were described.[6] Under the term "porphyritic dolerite" he described the well-known porphyritic essexite occurring on the hillside north of Lennoxtown. The teschenites of the east of Glasgow are described as micaceous dolerites, and several of the quartz diabase sills are described under no particular name. From his descriptions the sills of Clauchland and Dippin in Arran are also probably teschenites.

In the same year Professor J. W. Judd began his researches on the Tertiary volcanic rocks of the Western Isles of Scotland.[7] Since that time a number of memoirs on the same subject have appeared from his pen, all of which contain valuable additions to the petrology of Western Scotland. In 1883 appeared a paper on the Tachylytes of the Western Isles, with Professor G. A. J. Cole;[8] in 1885, on "The Tertiary and Older Peridotites of Scotland";[9] and, in 1886, on "The Gabbros, Dolerites, and Basalts of Tertiary Age in Scotland and Ireland."[10] In 1888 appeared Dr. J. J. H. Teall's monumental work, "British Petrography," in which numerous Western Scottish rocks are described and figured. Dr. Teall first recognised the teschenitic affinities of the rock of the Necropolis Hill in Glasgow,[11] and

[3] Sitz. Akad. Wiss. Wien., xlvii. (1863), pp. 260-262.
[4] Zeitsch. d. deut. Geol. Gesell., xxiii. (1871), pp. 1-124.
[5] *G.M.*, vol. ix. (1872), pp. 1-10; 536-545.
[6] *Q.J.G.S.*, xxx. (1874), pp. 529-567.
[7] *Q.J.G.S.*, xxx. (1874), pp. 220-302.
[8] *Ibid.*, xxxix. (1883), pp. 444-465.
[9] *Ibid.*, xli. (1885), pp. 354-418.
[10] *Ibid.*, xlii. (1886), pp. 49-97.
[11] Brit. Petrog. (1888), p. 194.

Digitized by Google

also the well-marked differences between the Newer Palæozoic and Tertiary dykes of the South of Scotland and the North of England.[12] Professor Judd maintained the same distinction in his paper of 1889.[13] A paper by the same author in 1893 described some of the Tertiary intrusions in the west of Arran.[14] The presidential address by Sir A. Geikie to the Geological Society in 1892 gave many details of the rocks within the scope of this paper.[15] From this point onward papers on Scottish petrology become too numerous to be mentioned individually. Only those of outstanding importance will be mentioned. In 1895 appeared Dr. Corstorphine's memoir on the eruptive rocks of the South of Arran.[16] In 1897 appeared Sir A. Geikie's "Ancient Volcanoes of Great Britain," a book from which all workers in the igneous rocks of Scotland must start. It contains a most comprehensive and valuable survey of all pre-existing knowledge of the rocks dealt with in this paper. In 1897, too, appeared the Geological Survey Memoir on the Cowal District, in which Mr. Clough established the pre-Tertiary age of the great E.-W. dykes. Since 1900 Survey Memoirs and Annual Summaries of Progress have given a good deal of information, especially in the way of chemical analyses. The Memoirs on N. Arran and Bute (1903), on "The Tertiary Igneous Rocks of Skye" (1904), and "The Geology of the Small Isles" (1908) must be specially mentioned. The two latter districts lie somewhat outside our territorial range; and, moreover, have been so fully dealt with by Mr. Harker as to require very little attention in this paper, which deals more with the district within easy reach of Glasgow. In these *Transactions* may be mentioned two recent papers, one by Mr. P. MacNair "On the Dolerites of the Neighbourhood of Glasgow,"[17] and by Mr. R. Boyle "On the Ultrabasic Rocks of the Lugar and Cumnock Districts."[18]

[12] Brit. Petrog. (1888), p. 206.
[13] *Q.J.G.S.*, xlv. (1889), p. 209.
[14] *Ibid.*, xlix. (1893), pp. 536-565.
[15] *Q.J.G.S.*, xlviii. (1892). Proc., p. 60.
[16] Tscherm. Min. u. Petr. Mitth., xiv. (1895), pp. 443-470.
[17] *Trans. Geol. Soc. Glasgow*, xiii., pp. 56-86.
[18] *Ibid.*, xiii., pp. 202-223.

Digitized by Google

III. Classification.

Broadly speaking, the post-Carboniferous intrusive rocks fall into three main groups—

(1) The great E.-W. dykes and their associated sills of quartz-diabase or dolerite. The age of these is almost certainly Permo-Carboniferous.

(2) The alkalic group of teschenites and essexites, with their ultrabasic and other varieties—these seem to be connected with the Permian vulcanicity of Ayrshire.

(3) The extremely varied group of intrusive rocks of undoubted Tertiary age—in our district occurring chiefly in the Island of Arran.

The minuter subdivision of these groups is set forth below. About three hundred rock-slides have been examined in the course of this work, including a fine collection of sections of igneous rocks from Ayrshire and Arran, for the kind loan of which I have to thank Mr. David Ferguson, F.R.G.S., Mem.Inst.M.E.

IV. The Quartz-Diabase Dykes and Sills.

One group of these rocks has been fully described in my paper on the "Geology and Petrology of the Igneous Intrusions of the Kilsyth-Croy District."[19] They appear almost invariably as very long, massive, vertical-sided dykes, extending in an E.-W. direction, sometimes for many miles. With them are associated great sill or laccolite-like protrusions into the adjacent strata. These rocks are grey to black in colour, and of medium grain, although there occur sporadically towards the interior of the masses lighter coloured and much coarser types. The marginal facies is a dense black basaltic rock, sometimes porphyritic with small, glassy felspars. Microscopically they are found to consist of an interlocking framework of labradorite and augite, with iron ores, in a groundmass of quartz and micropegmatite. In the more acidic, coarser grained rocks above mentioned the last-named constituents become very abundant. The average proportions of the essential constituents in the normal grey

[19] *Geol. Mag.* (v.), vol. vi. (1909), pp. 299-309; 359-366.

Digitized by Google

medium-grained rock, of which the great bulk of these intrusions is composed, are given below. These have been calculated from the "norm" of an analysis of the rock of Auchinstarry Quarry, Kilsyth.[20]

	Per cent.
Plagioclase (chiefly labradorite),	48
Pyroxene (augite and hypersthene),	32
Quartz and micropegmatite,	9
Iron ores,	8
Water, CO_2, &c., (= alteration products),	3
	100

The plagioclase is highly zonal, a medium labradorite forming the core of the crystal, and oligoclase the margin. Where adjacent to an area of micropegmatite, the felspar of the margin is often seen to be continuous with the felspathic base of the micropegmatite. The pyroxene is a pale yellow to colourless augite, with the sahlitic striation parallel to the basal plane, which, in conjunction with simple twinning, gives rise to "herring-bone" structure. Occasionally it appears to take on the pleochroism and polarisation colours, but not the straight extinction, of hypersthene. Chemical analysis of the augites of similar rocks has shown in a number of cases that the mineral contains an abnormally large proportion of the hypersthene molecule.[21] The phenomenon has been explained as a submicroscopic intergrowth of the orthorhombic and monoclinic pyroxenes. The iron ore consists of an intergrowth of magnetite and ilmenite, or of the latter only. Quartz and micropegmatite, the latter varying in freshness and grain with the freshness and grain of the rock, fill up the interspaces. Numerous apatite needles penetrate all constituents, least in the pyroxene and most abundantly in the micropegmatite.

The usual type of structure is that termed subophitic by Professor W. W. Watts. In the most typical rocks early basic unzoned felspars may be found entirely enclosed in augite. Conversely, the later, highly zonal felspars occasionally enclose idiomorphic crystals of augite. This variation may frequently be found within the limits of a single slide, and may be

[20] *See* petrological part of above paper.

[21] For petrological detail and references, *see* Kilsyth-Croy paper, *op. cit.*

Digitized by Google

explained as due to a continuous separation of felspar substance from the magma during its crystallisation, the separation of augite being episodal, beginning after the first crop of basic felspars, and ending before the crystallation of the later acidic felspars.

As pointed out in the paper on the Kilsyth-Croy intrusions, the normal quartz-diabase is a widely distributed type of igneous rock throughout the world, and exhibits a remarkably uniform chemical composition.

Age.—There is now a general consensus of opinion that these intrusions should be assigned to the late Palæozoic. They cut all strata to the Upper Coal Measures, but are not found in the Permian red sandstones of the West of Scotland. Mr. Clough found that the small N.W.-S.E. Tertiary dykes invariably cut the E.-W. dykes in the Cowal district.[22] These observations were confirmed by Mr. Gunn in the Cumbraes.[23] Much additional evidence has been found during the recent work of the Geological Survey in Central Scotland.[24]

Distribution.—The E.-W. dykes of Rowardennan, Whistlefield (Loch Long), Dumbarton, Blanefield, Dunoon, Lochgoilhead, Carrick, and Bishopbriggs belong to this group, as well as the intrusions of Kilsyth, Croy, Stirling, Milngavie, and the large mass to the south-east of Old Cumnock.

V. The Alkalic Group.

Since the publication of the British Petrography a group of basic rocks of highly alkalic nature has been recognised in the South of Scotland. They comprise teschenites and essexites, which pass gradually by an increase in basicity to picrites of the Inchcolm type, and by a decrease in alkalinity to olivine gabbros and dolerites which are, however, more alkalic than the ordinary types. This group is characterised by the association of original analcite, with plagioclase, orthoclase (probably a soda-bearing variety), purplish titaniferous augite, and

[22] Geol. of Cowal (1897), p. 139, 140, 156.

[23] Sir A. Geikie, "Ancient Volcanoes of Great Britain" (1897), vol. i., p. 407.

[24] A general summary of opinions as to age is given in *G.M.* (v.), vol. vi. (1909), p. 303.

Digitized by Google

occasionally a green ægerine-augite, olivine, a deep red-brown barkevicitic amphibole, biotite, and ilmenite. Nepheline has been observed by Lacroix in the beautiful porphyritic essexite of Crawfordjohn.[25]

These rocks occur as large and small sills, although in general smaller than the quartz-diabase intrusions. They are not associated with E.-W. dykes, and rarely with dykes of any particular direction or magnitude.

Teschenites.—In hand-specimens these are medium to fine grained, grey to black rocks, in which olivine, augite, and biotite may frequently be recognised. Analcite is abundant as large white, grey, or pink patches studded with small crystals and flakes of the darker minerals. A very distinctive rock is one containing plagioclase, analcite, augite, and olivine, in which the augite appears prominently as lustrous black idiomorphic crystals, occasionally reaching 1 inch in diameter. Good examples of this type are found on the slope of the Campsie Fells north of Lennoxtown, at Crawfordjohn in Lanarkshire, and at Lugar.[26]

Microscopically the teschenites consist of plagioclase and analcite, with augite, olivine, biotite, hornblende, and ilmenite. The felspar is highly zonal, the central parts giving the extinction angles of medium labradorite. Its relation to the augite is generally subophitic. Untwinned felspar occurs interstitially in subordinate amount. Some of the latter is probably soda-orthoclase, or even anorthoclase, but not sufficient evidence has been obtained on this point. The augite is the purplish titaniferous and soda-bearing variety. The colour deepens towards the margin; and occasionally a crystal purple coloured in the interior changes gradually to pale green on the margin, especially if it abuts on an area of analcite. The latter sometimes contains a few small deep green crystals of ægerine. The olivine is generally in rather rounded crystals, and is very fresh. When alteration has proceeded to any extent the product is a deeply coloured green serpentine. Analcite occupies all the interspaces. Its freshness varies with the freshness of

[25] Comptes Rendus (1900), p. 1273.

[26] In a recent survey of the Dalmellington district, another occurrence was found as a small intrusion in the Permian vent of Carclout, 1 mile south-west of Patna.—G. W. T., Sept., 1909.

Digitized by Google

the rock, but in the larger areas it becomes turbid with a brown dust towards the margins. Radial zeolites and calcite are the ultimate products of its decomposition. It is generally charged with a great number of apatite needles, together with small flakes of biotite, crystals of deep red-brown barkevicite, ægerine, and occasionally a detached crystal of plagioclase, olivine, and augite. The enclosed plagioclases occasionally present ill-defined boundaries to the analcite, as if some corrosion of the former had taken place. This is probably due to the pneumatolytic replacement of the felspar by the analcite,[27] but this is a very local phenomenon. As a rule, the plagioclase presents quite sharp boundaries to the analcite.

The above facts leave practically no doubt that the analcite is a primary constituent of the rock, and has been the last to crystallise. The latter process may have been so drawn out as to include the pneumatolytic changes due to the rock "stewing in a concentrated solution of sodium carbonate," as expressed by Messrs. Bailey and Grabham.[28] Although Lacroix states that he has found nepheline in the Crawfordjohn rock, this mineral has not yet been recorded in the other teschenites and essexites of South Scotland, and there is no evidence whatever that the analcite is secondary after nepheline.[29]

Distribution.—Probably the most typical locality for teschenites and their associated rocks in the West of Scotland is that of Lugar, which is described in more detail later. These rocks also occur amongst the sills intrusive in the Coal Measures near Dalmellington, in the east of Glasgow (Necropolis Hill), and at Cathcart, Ardrossan, Saltcoats, Troon, and Stewarton.

Picrite and other Rocks associated with Teschenite.—This group will be best treated by describing the remarkable variations occurring in the Lugar sill. This intrusion, which is about 140 feet thick, and has been injected into the Millstone Grit series, is magnificently dissected by the Bellow and Glenmuir Waters, so that practically every foot of its thickness may be

[27] Bailey and Grabham, *G.M.* (v.), vol. vi. (1909), p. 256.

[28] *Ibid.*, p. 253.

[29] Since this was written, nepheline has been recorded in the Cathcart teschenite, the Lennoxtown essexite, and a weathered theralite from Barshaw, near Paisley. Flett and Bailey, Summ. *Prog. Geol. Survey* for 1908, p. 44.—G. W. T., Sept., 1909.

Digitized by Google

examined. Starting at the upper margin, we first encounter a dense black basaltic marginal facies passing gradually into a perfectly typical teschenite. Proceeding downwards, the proportion of the coloured minerals relative to analcite and felspar gradually increases, the rock becomes slightly finer grained, and the augite, olivine, and hornblende take on idiomorphic forms, so that the structure of the rock becomes like that of a lamprophyre. In fact, the composition and structure at this point are identical with that of the rock known as camptonite. It is noteworthy that whole sills, like that of Cathcart—in fact, most of the smaller alkalic sills and dykes—are composed of this camptonitic variety. The thick dyke crossing the Lugar Water between Old Cumnock and Lugar is a typical example. Still passing downwards in the sill, the felspar gradually fails and finally disappears, leaving a rock composed of augite, olivine, hornblende, biotite, and ilmenite embedded in a groundmass of analcite. The coloured minerals are perfectly idiomorphic, and the rock is identical with the monchiquites of Rosenbusch. Now the analcite begins to fail, and in the centre of the sill disappears entirely, leaving a beautiful rock consisting mainly of olivine in all stages of alteration to green, blue, yellow, and colourless serpentine, purple augite, deep red hornblende and biotite, and ilmenite. This rock is identical with the picrites of Inchcolm and Barnton, and makes up the greater part of the Lugar sill. Passing now to the lower margin, we find the same changes in the reverse order, until at the actual margin teschenite, with its basaltic marginal facies, is found. Specific gravities of selected specimens taken from various parts of the sill show a regular variation from top to bottom. The following table gives the specific gravities, arranged in that order:—

Upper part.	Teschenite, coarse, with very abundant analcite (R1044),[30]	2·64
	,, normal (R1046),	2·70
	,, camptonitic variety (R1054),	2·98
	,, monchiquitic variety (R1048),	2·99
Central	Picrite (R1049)	3·01
Lower part.	Teschenite, camptonitic variety (R1051),	2·81
	,, normal (R1052),	2·77

The picrite occupies approximately five-eighths of the total

[30] The numbers given in brackets are those of specimens in the collection of the Geological Department, Glasgow University.

Digitized by Google

thickness, the upper margin of teschenite, &c., one-quarter, and the lower one-eighth. The lower margin of the picrite is rather sharply marked off from the underlying teschenite.

In his valuable and comprehensive paper on the Lugar intrusions, Mr. R. Boyle has recognised the transition from picrite to teschenite, and has described the intermediate rocks as doleritic picrite, olivine dolerite, and olivine basalt.[31]

The phenomena described above are perhaps best explained as a simple case of gravity differentiation. The original magma was a rather basic teschenite, and was intruded in a highly heated and liquid condition. The sudden cooling at the contacts produced layers of teschenite with sharp margins of basalt, both at top and bottom, thoroughly insulating the still highly liquid interior. In this the heavier minerals sank as they formed into the lower strata of the magma, until increasing viscosity checked this movement. The greater the degree and duration of liquidity the more thoroughly would this density stratification take place. In a later stage of crystallisation, if viscosity had not become too great, the felspars, as they crystallised, would tend to rise through the magma. This would explain the formation near the top of the sill of a rock very rich in felspar and analcite (specific gravity 2·64), which bears the same relation to teschenite as nepheline syenite does to theralite. The very irregular and local distribution of this type of rock may be then explained as due to the obstruction caused by increasing viscosity and the clouds of new minerals being formed, preventing the regular stratification exhibited in the lower parts of the sill. The greater thickness of the upper layer of teschenite is easily explained on this hypothesis, for the upper layer consists of the contact plus a certain thickness of acidic teschenite due to the draining away of the heavier minerals into the monchiquite and picrite strata, whereas the lower teschenite consists of the contact layer only.

That such gravity differentiation is *a priori* possible, and has occurred in many magmas, has been amply proved by Daly.[32] The explanation has also been applied with great

[31] *Trans. Geol. Soc. Glasgow*, xiii. (1908), pp. 202-223.

[32] R. A. Daly, "Origin of Augite-Andesite," *Journ. Geol.*, vol. xvi. (1908), pp. 401-420.

Digitized by Google

success to the case of a highly olivinic ledge in the Palisade quartz-diabase sill, New Jersey.[33]

The Lugar picrite is identical with those occurring at Inchcolm, Barnton, and Blackburn, in the East of Scotland. The Inchcolm rock is also associated with teschenite, which occurs on the margins of the sill.[34] The occurrence at Barnton, according to Sir A. Geikie, presents almost exactly the same appearances as the Lugar sill, the upper layer of dolerite (= teschenite) being much thicker than the lower.[35] Dr. Falconer has described a sill at Ardrossan in which transitions from picrite to hornblende and mica dolerites (= teschenites) occur.[36] Sir A. Geikie mentions a picrite similar to that of Inchcolm from Lethan Hill, near Waterside, in the Dalmellington district.[37]

Essexites.—This group of rocks may be regarded as the granitic representative of the teschenites. They contain the same set of minerals, but the structure is hypidiomorphic, not diabasic as in the teschenites. The proportion of analcite, however, is distinctly smaller, but that of red hornblende and biotite larger. The plagioclases are long and lathy, and frequently have a sub-parallel arrangement. Augite and olivine, as a rule, do not occur in such large crystals as in the teschenites, although the augite occasionally occurs in large porphyritic crystals. Deeply coloured and idiomorphic red hornblende (barkevicite) and biotite are abundant in the essexites. Analcite generally occurs in small water-clear triangular areas between adjacent felspars.

Olivine Gabbros and Dolerites.—By the gradual failure of analcite and the disappearance of hornblende and biotite the essexites pass into rocks composed of plagioclase, purple augite, olivine, and ilmenite, the structure remaining hypidiomorphic. The teschenites frequently show a similar transition, but the

[33] J. Volney Lewis, "Ann. Rpt. of State Geologist for 1907, Geol. Survey of New Jersey" (1908), p. 129.

[34] Campbell and Stenhouse, "Geology of Inchcolm." *Trans. Edinburgh Geol. Soc.*, ix. (1908), p. 121.

[35] "Ancient Volcanoes of Great Britain" (1897), vol. i., p. 450.

[36] *T.R.S.E.*, vol. xlv., pt. iii. (1907), pp. 601-609.

[37] "Ancient Volcanoes," vol. ii., p. 67. There are at least four other occurrences of picrite associated with teschenite amongst the sills of this district.—G. W. T., Sept., 1909.

Digitized by Google

structure remains diabasic. There is no diminution, however, in the size of grain. These rocks have therefore the mineral composition of olivine gabbro and dolerite, but they would doubtless be found, on chemical analysis, to be richer in alkalies than normal gabbro or dolerite, although less rich than the essexites and teschenites. The transition to olivine gabbro and dolerite frequently takes place in the same mass. The rocks represent a portion of the magma locally poorer in alkalies than that giving rise to the essexites and teschenites. Occasionally a small area of clear analcite may be discovered wedged in between adjacent felspars.

Distribution.—The great sills of Craigie and Dundonald, in the north of Ayrshire, are essexites passing locally into olivine gabbros, as are also the sills of Benbeoch, Benquhat, and others in the Dalmellington district. The olivine dolerites are well represented by the sills at Quarrelton, near Paisley.

Age of the Alkalic Group.—This group is considered to be the hypabyssal or plutonic phase of the Permian vulcanicity of Western Scotland, for the following reasons:—

(1) They are intruded into all formations up to and including the Permian red sandstone of Ayrshire.

(2) They become more numerous as the Permian volcanic districts of the West of Scotland are approached. They are most numerous in the immediate neighbourhood of the areas in Central and Southern Ayrshire, where Permian volcanic necks and lavas are developed. They are occasionally found as plugs or as intrusions into the ash of a Permian neck; and at Howford Bridge, near Mauchline, they cut the Permian lavas also.

(3) The alkalic intrusions and the Permian lavas of Ayrshire are petrologically consanguineous. Both contain the same minerals, and the essential minerals have the same peculiarities in each. The lavas comprise types ranging from basic analcite basalt, through olivine basalt and limburgite, to almost pure augite-olivine-iron-ore rocks practically devoid of felspar, thus corresponding to the teschenite-picrite series of the alkalic group.

The alkalic group is probably slightly younger than the quartz-diabase dykes and sills. The latter do not occur within the Permian red sandstones, which are, however, cut by the

Digitized by Google

alkalic intrusions. On the East Coast, however, Messrs. Campbell and Stenhouse have recorded an E.-W. dyke of quartz-diabase cutting the teschenite and picrite of Inchcolm.[38] It is probable, therefore, that the two groups are nearly co-extensive both in time and space.

VI. The Tertiary Intrusions.

This section will be limited to the discussion of those intrusions occurring in the western counties and the Clyde islands. Those of Skye, Mull, and the Small Isles have already been admirably dealt with by Mr. Harker.

The Tertiary intrusions of our district comprise a great variety of rocks ranging in composition from acid to basic. They are most typically developed in Arran, but great numbers of small dykes, with a fairly constant N.W.-S.E. trend, are to be found on the mainland. These cut the youngest sedimentary rocks known in this area, and are to be found piercing the earlier igneous rocks. They are thus relegated with a fair amount of certainty to the only known period of igneous activity subsequent to the Permian in the West of Scotland—the Tertiary.[39] The majority of the Tertiary intrusions of the West of Scotland have been so often and so well described that it is only necessary here to indicate as briefly as possible their main classificatory characteristics. They will be classified in order from acid to basic.

Granites.—In our district these occur only in Arran. They form the great circular boss in the north of that island, and their denudation has given rise to the picturesque Goatfell group of mountains. Petrographically they are biotite granites, containing quartz, orthoclase, oligoclase, and biotite, with frequent granophyric structures. The granite which forms part of the ring of intrusive rocks surrounding the great volcanic vent of central Arran contains hornblende, and, by a gradual increase in the proportion of that mineral, passes into quartz-diorite and diorite. The biotite-granites closely resemble the rocks of the Mourne Mountains of Ireland, whilst the horn-

[38] *Op. cit.*, p. 130.

[39] "Ancient Volcanoes of Great Britain" (1907), vol. i., p. 408.

Digitized by Google

blende-bearing varieties are similar to the Tertiary granites of Skye and Mull.[40]

Quartz-Porphyries and Felsites.—These rocks, too, are found only in Arran, and have been described by Zirkel, Allport, Judd, Teall, and Harker. The quartz-porphyries are very uniform in type. They usually have a grey, yellow, or white crypto- or micro-crystalline groundmass with numerous phenocrysts of quartz, sanidine, and oligoclase. The felsites have the same groundmass, but phenocrysts are rare or absent. Spherulitic varieties have been found at various places in Arran.

Pitchstones.—These well-known rocks have been so often described that it is unnecessary here to treat them at length. A comprehensive account, with a bibliography, may be found in the Geological Survey Memoir on N. Arran, S. Bute, &c. The commonest variety is a nearly colourless glass full of beautiful feathery green microlites, also containing phenocrysts of quartz, plagioclase, orthoclase, augite, and magnetite. Some varieties are beautifully spherulitic. As a whole, their affinities are with the dacite and andesitic glasses rather than the rhyolitic.

Trachytes.—A few trachytic dykes have been found in Argyllshire.[41] These are pale brown, fine-grained rocks occurring as thin dykes with spherulitic margins. They consist of lathy orthoclase, with scales of biotite, altered pyroxene, and a few granules of magnetite. The spherulites of the margin are enclosed in a pale brown glass.

Gabbros.—Typical gabbros have been described by Mr. Harker from the plutonic girdle of the great volcanic vent of central Arran. These are medium-grained rocks, consisting of labradorite and augite in subophitic relations, with iron ores. Olivine does not occur. Specimens containing a large amount of orthorhombic pyroxene have been obtained near Glenloig Farm. Petrographically these are norites. A quartz-hyperite containing plagioclase, augite, bronzite, quartz, brown and green hornblende, with interstitial patches of micropegmatite, has been described from Creag-nan-Mult.

[40] Harker, "Geol. of N. Arran, S. Bute," &c. Mem. of Geol. Survey (1903), pp. 104-106.

[41] Memoirs of Geol. Survey, "Geol. of Cowal" (1897), pp. 166-171; "Geol. of Mid-Argyll" (1905), p. 121.

Digitized by Google

Teschenites.—The great sill at Dippin, in the south of Arran, is composed of a rock identical with the Permian teschenites above described. From Allport's description, the Clauchland sill also appears to be a teschenite.[42] These rocks are considered to be of Tertiary age by the Geological Survey officers.[43] They are intrusive into the so-called Triassic sandstones of Arran. These sandstones rest unconformably on the Carboniferous, and derived Carboniferous fossils have been found in a pebbly band near the Cock of Arran. The youngest rocks underlying them are Lower Coal Measures. This evidence is, of course, not decisive as to their Triassic age. The latter correlation is based on the discovery of marls associated with Rhætic beds in the central volcanic vent, identical with the marls forming the upper part of the red beds in the south of Arran.[44] The resemblance of these sandstones to the lower false-bedded sandstones of Ballochmyle is admitted. According to Mr. D. Ferguson, who has recently made an extensive survey of the Ayrshire Coalfield, there has been continuous sedimentation from the red sandstones of the Upper Coal Measures to the red sandstones of the Mauchline basin, unless the intercalated lavas be considered a break.[45] But these are interleaved with sediment, and enclose masses of sandstone as if the lava had rolled along a soft sea-floor. The Mauchline sandstones might even be considered as the highest part of the Upper Coal Measures. It is possible, therefore, that these intrusions will ultimately be classed with the Permian teschenites above described. Whatever the age of the red sandstones of Ayrshire and Arran, for the present the teschenites intrusive in the red rocks of Arran must be doubtfully classed as Tertiary until more decisive evidence as to their age is obtained. It is noteworthy that teschenites have not yet been found in any of the other Tertiary volcanic districts of Scotland or Ireland.

Andesitic Dolerites (*Augite Andesites*).—This group comprises the more acid types among the basic Tertiary dykes. These dykes are usually thin, short, and conform to a general

[42] *Q.J.G.S.*, xxx. (1874), p. 563.

[43] Geol. Sur. Mem. "Geol. of N. Arran and S. Bute" (1903), p. 112.

[44] Geol. Sur. Mem. "Geol. of N. Arran and S. Bute" (1903), p. 67.

[45] Unpublished paper on the "Ayrshire Coalfield," read to the Glasgow University Geological Society; and oral communications.

Digitized by Google

N.W.-S.E. direction. The commonest variety, seen in thin section, shows a mesh of rather short, lathy felspars, with interstitial granular augite, embedded in a usually abundant groundmass of light-coloured glass, which is, however, frequently darkened by diffused magnetite dust. Rather rarely the ophitic relation occurs between felspar and augite. Large, glassy plagioclases are the only porphyritic constituents. These are medium labradorites, usually beautifully zoned with inclusions of groundmass (see Plate XIX., Fig. 5). The glassy groundmass is sometimes patchy, and in the Eskdalemuir dyke described by Sir A. Geikie,[46] also in some of the Cowal dykes,[47] the glass has segregated into a thick central band, in which a curious arrangement of vitreous prisms, with thin sheaths of more lithoidal material, is seen. Tachylytic selvages are common in the Cowal dykes of this type.

Most of the Tertiary dykes of Ayrshire belong to this group, as, *e.g.*, the rather lengthy one near Coylton. They are also found in Arran, Bute, the Cumbraes, and Argyllshire. The Tertiary lavas of Ben Hiant, in Ardnamurchan, described by Professor Judd under the name of "younger augite andesite," belong to this group, as do also the andesitic dolerites of the Cleveland, Acklington, and Tynemouth dykes in the North of England.[48]

Olivine Dolerites and Basalts.—These comprise dykes of considerably more basic character than the preceding group. The prevailing type is a fine-grained but holocrystalline rock, consisting of a groundmass of plagioclase ophitically enclosed in small plates of brown or purplish augite. Irregular grains of iron ore, and olivine in small grains or porphyritic crystals, are abundant. Other phenocrysts are rare, and, in contradistinction to the andesitic dolerites, a glassy or cryptocrystalline groundmass is also rare. Tachylytic selvages, however, are rather common.

By far the greater number of the small N.W.-S.E. dykes belong to this group. They occur in Arran, the Cumbraes, and the Cowal district in the greatest profusion. Many of the

[46] "Ancient Volcanoes of Great Britain" (1897), vol. ii., pp. 127, 133.

[47] "Geol. of Cowal" (1897), p. 133.

[48] Teall, *Q.J.G.S.*, xl. (1884), p. 209. Also Brit. Petrog. (1888), p. 200.

Digitized by Google

dykes of the Ayrshire and Renfrewshire coast belong here. A typical example is the Deil's Dyke, near the Heads of Ayr. This is a coarse-grained ophitic olivine dolerite, with porphyritic olivine and felspar.

Conclusion.—Here must conclude this necessarily imperfect survey of the post-Carboniferous igneous rocks of the West of Scotland. Many gaps in our knowledge must be filled before any classification can be said to be complete. It is hoped that the one adopted in this paper, imperfect and provisional as it is, will prove useful, at least in correlating and exhibiting in one view our present-day knowledge of these most interesting series of igneous rocks.

EXPLANATION OF PLATE.

Fig. 1.—Teschenite (camptonitic variety), old quarry near the Castle, Cathcart. Ord. light, × 21.

Idiomorphic augite, olivine, hornblende, biotite, iron ores, and plagioclase in a groundmass of analcite. Panidiomorphic structure. Note area of analcite in centre of field pierced and bridged by augite in all directions. Olivine can be seen just above the central patch of analcite. Flakes of biotite occur here and there; but the hornblende, although abundant in small crystals, is not well seen.

Fig. 2.—Teschenite (camptonitic variety), upper part of picrite sill, near Bellow Bridge, Lugar. Ord. light, × 21.

Same minerals and structure as in fig. 1, but the rock is coarser, and contains even less felspar. Fresh olivine in the centre and on extreme left of field. Hornblende well seen at the bottom of the field, and also to the left of the central olivine. Biotite on extreme right. Augite in numerous small granules. The light-coloured groundmass is plagioclase and analcite, the latter in excess.

Fig. 3.—Hornblende picrite (Inchcolm type), Bellow Water, Lugar. Ord. light, × 11.

Hornblende (centre of field) enclosing olivine. Olivine, almost completely serpentinised, comprises most of the remainder of the field, and is especially well seen at the top right-hand corner. Augite, in numerous small granules, scattered over the field. Titaniferous iron ore associated with the hornblende.

Fig. 4.—Essexite (analcite-bearing), Craigie sill, 170 yards south of Harpercroft. Ord. light, × 21.

Olivine, augite, plagioclase, biotite, and hornblende with analcite. Structure thoroughly hypidiomorphic. Augite in centre of field. Numerous long lathy plagioclase crystals. Highly-refractive olivines towards top of field. An area of analcite, showing part

Digitized by Google

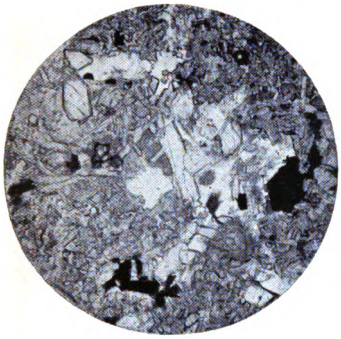


Fig. 1.

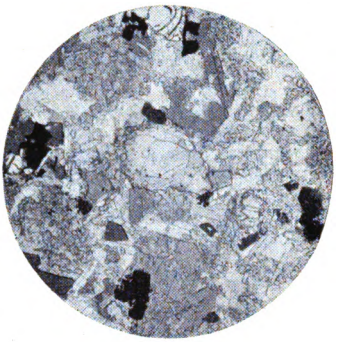


Fig. 2.

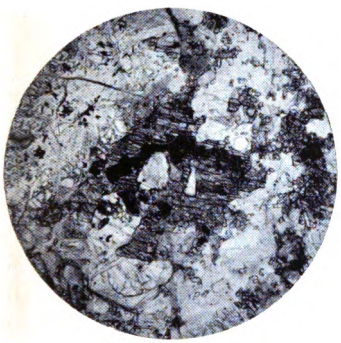


Fig. 3.

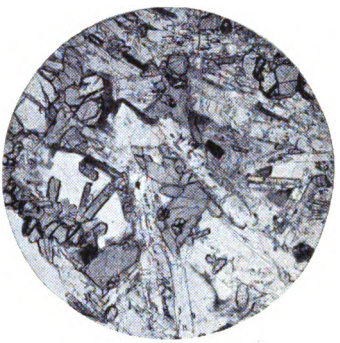


Fig. 4.

Fig. 5.

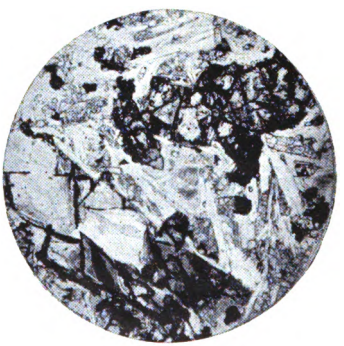


Fig. 6.

Micro-photographs of Post-Carboniferous Intrusive Igneous Rocks of the West of Scotland.

Digitized by Google

Digitized by Google

of its crystalline form, is seen to the left of the field. It is bordered with biotite, and encloses numerous idiomorphic crystals of augite.

I am indebted to Mr. David Ferguson for the negative from which this photograph was prepared.

Fig. 5.—Andesitic basalt, Tertiary dyke, foreshore near Birchpoint, Corrie, Arran. Ord. light, × 21.

Groundmass of plagioclase and augite in ophitic relations, with much dark-coloured glassy matrix (black in the field, and hardly distinguishable from magnetite). The only phenocrysts are well-shaped plagioclases, usually zoned both mechanically and chemically.

Fig. 6.—Olivine basalt, Tertiary dyke, Invercloy, Brodick, Arran. Ord. light, × 21.

A rather coarse-grained rock, consisting of plagioclase and augite in ophitic relations, with numerous large phenocrysts of serpentinised olivine.

Digitized by Google

No. XXV.—Isomorphism: Its Relation to the Chemical Composition and Physical Characters of Crystals.

By David P. M'Donald, M.A., B.Sc., Baxter Demonstrator in Geology, Glasgow University.

(Summary.)

[Read 5th April, 1909.]

The term "isomorphism" is derived from the Greek "isos," equal or similar, and "morphe," form, so that in the literal sense isomorphous substances are those which have similar crystalline forms. Mitscherlich, in his "Law of Isomorphism," connected up the chemical constitution of a substance with its crystalline form. Since then the term "isomorphism" has acquired a still more restricted meaning. Truly, isomorphous substances should be capable of mutually replacing one another in varying proportions in a crystal while the crystal still remains physically homogeneous. The recognition of the principle involved in the last sentence has been of great service to mineralogy. It has rendered possible the arrangement of minerals into mineral groups.

The rhombohedral carbonates provide a good illustration of a mineral group, consisting of isomorphous compounds. The similarity in chemical constitution is obvious, and the crystalline form—the rhombohedron—is the same in all the members of the group, thus—

Calcite, . .	$CaCo_3$	rhombohedron angle,		74° 55′
Magnesite, .	$MgCo_3$	,,	,,	72° 36′
Chalybite, .	$FeCo_3$	,,	,,	73° 0′
Calamine, .	$ZnCo_3$	,,	,,	72° 20′
Rhodochrosite, .	$MnCo_3$	,,	,,	72° 58′

There is a slight variation in the rhombohedron angle, and a similar variation is found when the physical properties, such as the specific gravity, the refractive index, the thermal conductivity, &c., are examined. Since the compounds are iso-

Digitized by Google

morphous, they should be found replacing one another in crystals. Intergrowths of members of this group resulting in "mixed crystals" are common. Certain fairly well-defined mixtures are recognised, and names have been given to them, thus—

Mesitite . .	is	$2\,MgCo_3$	$FeCo_3$	
Pistomesite . .	„	$MgCo_3$	$FeCo_3$	
Ankerite . .	„	$2\,CaCo_3$	$MgCo_3$	$FeCo_3$

In sideroplesite the main constituent is $FeCO_3$, but $MgCO_3$ up to about 12 per cent and $CaCO_3$ in smaller amount are also present. The colour of a crystal is frequently due to the presence of a small quantity of an isomorphous substance.

If much-crystallised mixtures are merely solid solutions of the constituents the crystal form and the physical characters of the "mixed crystals" ought to be intermediate between those of the components. This has been shown to be true in some cases, *e.g.*—

(1) The rhombohedron angle in mesitite lies between that of magnesite (72° 36′) and that of chalybite (73° 0′).

(2) The specific gravity of mesitite is 3·38, while that of magnesite is 3·06, and that of chalybite is 3·8.

The variation in the optical properties of such solid solutions is best studied in the felspar group. Albite (Na_2O, Al_2O_3, 6 SiO_2) and anorthite (CaO, Al_2O_3, 2 SiO_2) may be regarded as the extremes of the series, and the others as intermediate mixtures in varying proportions. As the chemical composition changes, optical characters, such as the extinction angle and the refractive index, also undergo a gradual change.

Besides giving rise to such intergrowths, isomorphous substances sometimes form overgrowths, in which case a crystal consisting of two or more layers results. Such "layer-crystals" may easily be prepared from solutions of the alums. When a crystal of chrome-alum is placed in a saturated solution of potash-alum the crystal continues to grow at the expense of the dissolved alum, the potash-alum forming a complete layer surrounding the chrome-alum crystal. Before the deposition of the potash-alum begins some of the chrome-alum goes into solution. That the process is not one of simple solution may

Digitized by Google

readily be proved by using quite small chrome-alum crystals. In this case the chrome-alum is dissolved, but at the same time a deposition of potash-alum goes on, and a replacement-crystal is obtained. When a large chrome-alum crystal is used the potash-alum appears to deposit immediately around it. There can be no doubt, however, that the replacement goes on as before, producing a layer of intermediate composition analogous to a " mixed crystal."

The replacement of masses of limestone by haematite is of this type, chalybite isomorphous with calcite being the original replacing substance, and oxidation afterwards converting the carbonate into the oxide.

Digitized by Google

No. XXVI.—Demonstration of Some of the Optical Properties of Minerals.

By David P. M'Donald, M.A., B.Sc., Baxter Demonstrator in Geology, Glasgow University.

(Summary.)

[Read 26th April, 1909.]

The chief object of the demonstration was to exhibit the figures shown by sections of minerals in convergent polarised light. The sections were arranged in two groups—

(1) Sections of uniaxial minerals cut perpendicular to the optic axis.

(2) Sections of biaxial minerals cut perpendicular to the acute bisectrix.

Group I.—Two sections of calcite, the one five millimetres thick, the other one millimetre thick, served to show the effect on the figure produced by thickening the section. The figures obtained by using sections of right- and left-handed quartz crystals were shown. By laying the one section above the other Airy's spirals were produced. The interference figures of various other uniaxial crystals were also to be seen.

Group II.—The interference figures produced by biaxial crystals were illustrated by sections of barytes, aragonite, and sanidine. A section of a sugar crystal cut perpendicular to one of the optic axis was shown, and the figure compared with that of a uniaxial crystal.

Several sections of pleochroic minerals were exhibited in order to show the marked variation in colour according to the direction of the section and the position of the section with regard to the vibration plane of the nicol-prism. Tourmaline, pennine, and hornblende were used as examples.

Slides containing small crystals of quartz and zircon illustrated the difference in refractive index of these minerals, and other rock sections were put under the microscope in order to show the difference in colour, cleavage, &c., of minerals.

Digitized by Google

No. XXVII.—The Geology of the Auchineden District, Kilpatrick Hills.

By G. W. Tyrrell, A.R.C.Sc., Assistant in Geology, Glasgow University, and N. Martin, A.G.T.C., B.Sc.

[Read 13th May, 1909.]

I. Introduction.

The district to be described comprises an area of about 7 square miles at the north-eastern extremity of the Kilpatrick Hills. This area is a wild and bleak moorland covered with heather and peat, lying at heights between 700 and 1200 feet above sea-level. It is bounded by the Glasgow-Drymen road on the east, by the boundary between Dumbartonshire and Stirlingshire on the south, and on the north and west by lines drawn through the Little Caldon and Thief's Hill respectively. We include, however, the small group of "necks" on Quinloch Muir just east of the Drymen road.

The main physiographic feature of this area is the terraced escarpment of the Calciferous Sandstone lavas of Auchineden Hill, on the north face of which occurs the well-known landslip of the Whangie. This escarpment, with that of the lavas near Kilmanan Loch, is separated by a broad valley from the swelling elevation marking the site of the Knockvadie vent. Further to the north is a wide, more or less level area of Calciferous Sandstone, dotted here and there with conical hills marking the sites of various volcanic necks, chief of which is the Little Caldon on Stockie Muir. The main stream is called Burn Crooks, which, later in its course, flows at the bottom of a fine gorge in the Calciferous Sandstone, which is known as Finnich Glen. The only reference of note to this district is one by Sir A. Geikie in his "Ancient Volcanoes of Great Britain." He gives a section[1] of "trachytic" sills invading the Upper Old Red Sandstone underlying the terraced escarpment of Lower Carboniferous lavas. We can endorse the general structural accuracy of this section, but the sills themselves are beautifully fresh olivine basalts. There is much justification, however, in

[1] Vol. i., p. 410.

Digitized by Google

calling them trachytes, as they weather with a light-coloured buff or pinkish crust, and the felspar laths frequently show a good fluidal structure. In the heart of broken blocks, and in the deep excavation of the puddle trench now being dug at Burn Crooks, the rock is a lustrous black or bluish basalt, which under the microscope is seen to be a fresh olivine basalt. In our field notes, indeed, this rock, and many others among the various escarpments, are entered as "blue-hearted trachyte." The officers of the Geological Survey have recently revised the geology of this district, but the results of their work have not yet been published. There are, however, a few short notes bearing on the geology of this district in the Summaries of Progress of the Geological Survey for 1905[2] and 1906.[3] A chemical analysis of the intrusion into the ash of the Little Caldon neck is given in the Summary for 1907.[4] The landslip of the Whangie is well described in Bell's "Amongst the Rocks round Glasgow."[5]

II. General Succession and Structure.

The rocks all belong to the Calciferous Sandstone series, and are arranged in descending order as follows:—

Lavas—("Porphyrites"), interbedded,	-	2000 feet.?
Tuffs,	about	100 ,,
Cement-stones,	,,	50 ,,
White and red sandstones,	-	1000 ,,

The general dip is from 10-15° slightly east of south. The *white and red sandstones* underlie the Quinloch, Stockie, and Dumbarton Muirs in the north of our district. They are pierced with numerous volcanic necks or associations of necks, of which the Little Caldon and the large composite neck at Knockvadie are the most important. Another group occurs on Quinloch Muir to the east of the Drymen road. Two or three small necks are associated with the lowermost lavas near the Whangie, at the north-eastern extremity of Auchineden Hill; whilst the neck known as the Thief's Hill, in the extreme west of our area, abuts directly on the lavas and tuff of the escarpment. A large E.-W. dyke traverses the sandstones immedi-

[2] P. 133.
[3] P. 91.
[4] P. 55.
[5] (1881), p. 57.

Digitized by Google

ately to the north of the Knockvadie vent, and there are many smaller dykes exposed in the various stream courses trenching the sandstones.

The *cement-stones* are thin and inconspicuous in this district. They consist of red and green calcareous shales, with thin ribs of sandstone, and are exposed only in the runnels on the north side of Auchineden Hill. The overlying *tuffs* are exposed in the same place, and are here composed of rather coarse fragments of volcanic material in a purplish paste. There is also an exposure near the Whangie where the rock is bright red in colour and coherent in rather hard, blocky masses. There are excellent exposures in the upper part of Burn Crooks. The rock is here very well bedded, and for the most part soft and crumbling. The finer muddy material predominates, but there are pebbly bands which are frequently consolidated into hard, slabby layers, and break into rhomboidal fragments owing to a perfect system of rhomboidal vertical jointing. A few large boulders of basalt are embedded here and there. The bedded lavas from the great fault-block of Auchineden Hill and the hills to the west, near Kilmanan Loch, are described later.

A problematic fault is mapped on the Geological Survey map, Sheet 30, as forming the northern boundary of the lavas of Auchineden Hill. It is continuous with the line of the E.-W. dyke. The authors regard the evidence as somewhat strong for an E.N.E.-W.S.W. fault bounding the southern margin of Auchineden Hill, and continuous up the remarkably straight valley of the upper part of Burn Crooks. This valley is regarded as partly determined by the fault line, against which the escarpments at the south end of Auchineden Hill end off very suddenly. Looking along this line from the west, there is a prominent notch in the Auchineden escarpments. The fault is supposed to die out to the east of Auchineden Hill, and also westward in the neighbourhood of the Thief's Hill. It attains its maximum throw at the sharp bend in Burn Crooks. To it is attributed the sharp change in trend of the escarpments at this point. There are one or two smaller parallel faults to the south, against which abut the smaller escarpments of the hill to the S. of Auchineden.

Digitized by Google

III. Detailed Description of the Sections.

Knockvadie.—The section in Burn Crooks at this locality is fairly continuous and clear. The E.-W. dyke ½ mile N. of the Knockvadie intrusion appears as a continuous ridge which is breached by the stream, forming a low cliff. It rises through horizontally bedded white sandstones. A little further south another smaller dyke occurs. Then for a short distance bedded tuff and agglomerate, with a slight southerly dip, occurs in the banks of the stream. It is not possible here, owing to lack of junction sections, to determine whether this is a true interbedded layer or whether it represents a "neck" in which the material is bedded. It is probably the latter. The sandstones here have a decided dip to the south. A thin sill of olivine basalt similar to that of the great Knockvadie intrusion appears a few yards to the south of the above agglomerate, and seems to be intrusive in another mass of agglomerate which immediately succeeds it to the south. Sandstones follow for a short distance, but soon give place to a complicated mass made up mainly of agglomerate, in which the great Knockvadie sill is intrusive (see Fig. 1).

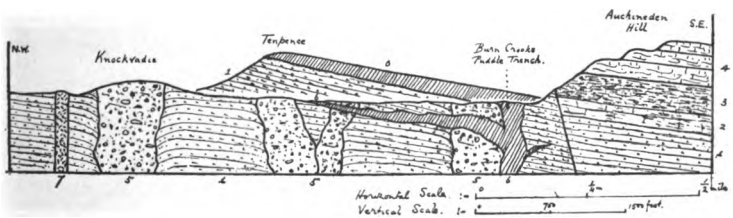


Fig. 1.—Diagrammatic section across Auchineden District.

1. Calciferous Sandstone. 2. Cement Stones. 3. Tuff. 4. Lavas. 5. Necks filled with Agglomerate. 6. Knockvadie intrusion. 7. E.-W. Dyke.

The hill of Tenpence, standing back from the main line of section, shows the Burn Crooks intrusion spreading out sill-wise and capping the hill.

The puddle trench now being excavated is situated about 200 yards N.W. of the right angle turn of Burn Crooks, designated "East Corner" on the 6-inch map. It is entirely within the sill. The latter is known from a series of borings to underlie the alluvium close up to the East Corner. In the western portion of the trench the fresh, hard, and compact

Digitized by Google

basalt suddenly becomes very soft and vesicular. The transition is gradual, although sudden. There is no sharp line of demarcation between the two rocks. The downward excavation of the trench shows that the width of this soft rock decreases with depth. It gives place to the normal rock again on the far western side. This soft, vesicular material led the authors, when examining the cores of the borings put down on the site of the trench, to conclude that the igneous rock here was not intrusive, but a lava with a slaggy top. That this conclusion was erroneous is shown by the field relations of the whole mass under question. The excavations show that the rock is undoubtedly intrusive, and that the soft portion has a considerable vertical but a very limited horizontal extension. Moreover, it passes laterally into the fresh intrusive rock. The journals of the bores (see Fig. 2) give some indication as to

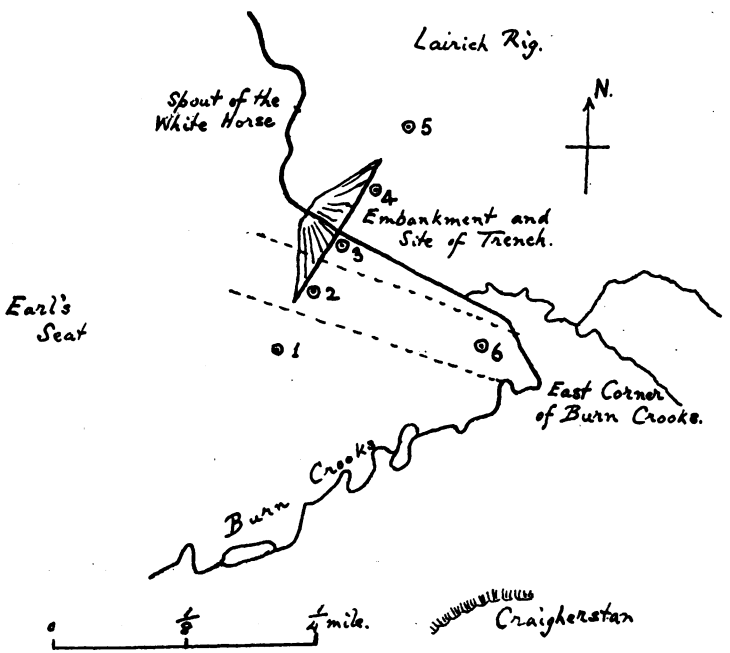


Fig. 2.—Sketch Map to show distribution of "soft" rock, probably due to fumarolic action. Burn Crooks.

Dotted lines—Bounderies of "soft" rocks. ⊙—Bores.

Digitized by Google

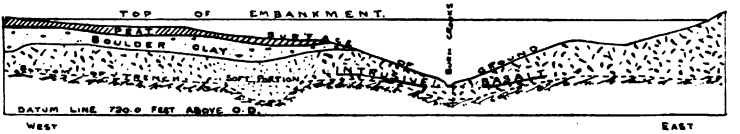
the direction of extension of this zone of "soft" rock. Bore No. (3) gives the following:—

Sand and clay (boulder clay),	10 feet.
Weathered basalt,	2 ,,
Hard, fresh olivine basalt,	150 ,,

Bore No. (2).

Peat, clay, &c.,		6 feet.
"Soft" rock	"Slag,"	10 ,,
	Very vesicular basalt,	18 ,,
	Hard, fresh olivine basalt,	36 ,,

Bores (1), (4), and (5) showed no "slag," but (6) began with several feet of slaggy material. Immediately to the N. of the trench, and W. of the stream, excavations for an outlet channel exposed the same rock. The zone of alteration therefore seems to extend in a N.W.-S.E. direction, and is bounded by the dotted lines in Fig. 2. Seen in thin section under the microscope, the structure is precisely similar to that of the normal fresh rock. The difference lies in the great development of vesicularity and the intense alteration suffered by every constituent.[6] The authors believe that this zone of alteration represents a fissure through which steam and heated waters were discharged in the moribund stage of the volcano's activity—in fact, that here is exhibited the site of a Carboniferous fumarole (see Fig. 3).



LONGITUDINAL SECTION OF PUDDLE TRENCH

MARKED AB ON SKETCH PLAN

Fig. 3.

On the N. side of the trench, in the stream bed, the sill abruptly gives place to bedded agglomerate or tuff, which it appears to transgress very sharply. At the first bend below the trench the agglomerate becomes very coarse. It is well exposed at the Spout of the White Horse and in the small

[6] *See* Petrology, p. 339 of this volume.

Digitized by Google

rennel entering the stream from the east at that point. At the base of the Spout a thin band of vesicular lava occurs.

The hill known as Tenpence, on the E. side of the stream, and the corresponding elevation on the W., are capped by the sill, which here appears to have tapered out more or less in conformity with the strata after rising vertically in the actual vent (see section, Fig. 1). Agglomerate belonging to two small associated necks occurs in the Glen of the House burn.

The appearances in this district therefore represent a vent filled with roughly bedded agglomerate and tuff, penetrated and covered by a sill or boss of olivine basalt. The stream, which has nearly severed the outcrop of the sill, has now cut down deep enough to expose the neck lying beneath.

Auchineden Hill.—This hill is a block of Calciferous Sandstone lavas bounded by E.-W. faults on the north and south. The lavas are underlain by tuff, a thin band of cement-stones, and by the Calciferous Sandstone. All the beds have a dip of 10-15° to the south-east. Starting at the Drymen road on Quinloch Muir, we first notice the group of small vents on the east side of the road. Some are composed entirely of agglomerate, and others are plugs of solid lava. The latter is an olivine basalt of Jedburgh type. One, about ¼ mile E. of the road, has a long, dyke-like protrusion striking off to the south.

On the N. slope of Auchineden Hill, to the W. of the road, tuff and cement-stones are to be seen in the small burns. In places the tuff is coarse enough to be called agglomerate. The cement-stone group consists of red and green sandy shale, with thin ribs of sandstone. A good exposure of coarse red tuff occurs a little E. of the Whangie. The tuff is surmounted by lavas, each of which forms a distinct terrace. Some of these are continuous and regular all round the north and west faces of the hill, but others appear to die out in a short distance. Beginning near the Whangie and traversing the hill in a south-easterly direction, fourteen distinct flows may be counted up to the strip of wood near Auchineden Lodge. At the northern ends of the first two flows occur two small tumps rising abruptly out of the flat terraces. These are composed partly of ash, and are undoubtedly small vents.[7] The Whangie itself,

[7] Grabham, *Summ. Prog. Geol. Sur.* (1905), p. 134.

Digitized by Google

occurring in the third lava, is a similar tump, which, when viewed from the south, appears to cut across the third and fourth terraces. It is also a neck. The lavas are olivine basalts, becoming more basic as one ascends in the series. As a rule, the lower flows are non-porphyritic, but the higher become increasingly porphyritic with felspar and olivine. Among the escarpments the rocks weather rather deeply with a buff or pinkish crust, and are only seen to be basalt when large blocks are broken. The new road of access to the Burn Crooks waterworks, along the S. side of the hill, has provided good fresh material for petrographical examination.

On the W. side of the hill the underlying tuffs and cement-stones are completely hidden by a thick covering of peat and boulder clay. Sections of the tuff, however, are numerous along the upper course of Burn Crooks.

The Whangie.—This remarkable landslip occurs in the vertical escarpment of the neck at the N. end of the third lava flow near the north-western extremity of Auchineden Hill. A great slice of rock, some hundred yards long and 10-15 feet wide, has moved forward, leaving a long, narrow, and deep gully between it and the escarpment. The tumbled remains of an earlier line of slip lie scattered on a steep, grass-covered talus slope immediately beneath. The whole escarpment is much fissured and jointed. There is, however, a prevailing slabby jointing running parallel to the north and south direction of the line of slip. The actual fissure, however, has opened along the large, curved surfaces known to quarrymen as "backs"[8] The two sides of the fissure fit perfectly. The bulges of the "backs" on the one side fit into the corresponding depressions on the other. This correspondence extends also to the rounded horizontal ridges which frequently cross the "backs." From a comparison of corresponding features on each side of the fissure it can be seen that the separated slice, although it has moved at least 4 feet from the cliff in many places, has not yet foundered more than 6 inches.

The following probably represents the history of the landslip. The original cliff became undercut owing to its fissured and broken condition, its disintegration giving rise to a considerable

[8] For illustration of good example, *see Trans. Glasgow Geol. Soc.*, vol. xiii. (1908), plate xiii., p. 248.

Digitized by Google

bank of talus. The undercut portion, becoming unstable, ultimately slipped off, the line of slip being determined by the general direction of the escarpment and of the predominant system of jointing. The slice of rock thus cut off ultimately forms an addition to the talus slope. The wearing back of all the escarpments in this district has probably been accomplished in this way by a succession of "Whangies." Some of the slips have been catastrophic, some have stood for a considerable length of time, as the present Whangie has done. Those left standing in this manner have their bases firmly embedded in the accumulated bank of talus, and slip downward and forward quite imperceptibly with lapse of time. The present Whangie has probably not been long in existence, for the curved "backs" which form the fissure are not weathered at all, and have a remarkably fresh appearance. It is a curious point that these "backs" are usually developed by a violent shock, such as blasting. They are never found in natural section, unless the spheroidal weathering so common in basaltic rocks be considered a phenomenon of the same nature. It is therefore a moot point whether the initial fissure of the Whangie was not developed by a shock of some kind. The only conceivable adequate shock likely in this district is an earthquake, and it is an interesting question as to whether an earthquake is capable of initiating a fissure along these potential surfaces of fracture.

Landslips of exactly the same kind, but much smaller than "The Whangie," are numerous in the district under consideration. They are to be found on the hillside ⅜ mile E. of "The Whangie," also in the escarpment of the eleventh flow of Auchineden Hill, and in the great escarpment above the upper course of Burn Crooks.

IV. Glacial Phenomena.[9]

The sections of which these notes are a record may be grouped as follows:—

(1) Those on the road of access to the reservoir.
(2) Those on the reservoir site and its neighbourhood.
(3) Those on the pipe track.

[9] This section has been contributed by one of the authors (N. M.), who, as resident engineer on the Burn Crooks Waterworks, has had the opportunity of observing and recording the details of many impermanent sections.

Digitized by Google

The road of access is 2⅞ miles long, and runs from the Drymen road at Auchengillan Farm westward along the dip slope of the Auchineden escarpments, terminating at the reservoir embankment. The excavations on this line consist of cuttings and of foundations for culverts and drains.

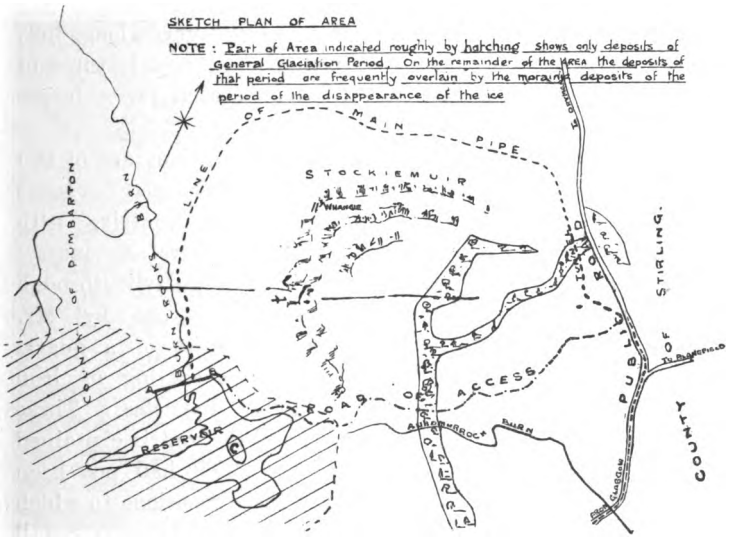

SKETCH PLAN OF AREA
NOTE : Part of Area indicated roughly by hatching shows only deposits of General Glaciation Period. On the remainder of the area the deposits of that period are frequently overlain by the morainic deposits of the period of the disappearance of the ice
MAIN PIPE LINE
STOCKIEMUIR
ACCESS ROAD
RESERVOIR
PUBLIC ROAD
COUNTY OF STIRLING.
COUNTY OF DUMBARTON

Fig. 4.

On the reservoir site and its neighbourhood there are two main excavations, viz., the puddle trench and the clay quarry, from which puddle for the embankment is obtained. The puddle trench, as presently excavated, is indicated on the sketch plan (Fig. 4) by a full black line marked AB. It is now about 300 yards long, has an average width on the top of 10 feet, and varies in depth from 12 to 45 feet. A longitudinal section of the trench is shown in Fig. 3. The puddle for the trench and some of the materials for the embankment are obtained from a peculiarly shaped knoll standing right in the middle of the reservoir site. The knoll is elliptical in plan, and is marked C on the sketch plan. The major axis of the ellipse is about 700 feet long, and lies N.E. and S.W.; the minor axis is about 200 feet long, and the height of the knoll above the surrounding ground about 30 feet. Excavation is being carried

Digitized by Google

on at the N.E. end of this knoll, and the knoll will be entirely removed when the works are finished.

The excavations on the pipe track consist of a trench about 2½ feet wide, and varying in depth from 4 to 14 feet. This trench extends for a total length of 9 miles, but only about 3 miles of it lie within the area described. On the line of the trench is a tunnel 7 feet in diameter and 700 yards long, but, as this work has only just been commenced, any features of interest in connection with it must be reserved for a future communication.

The glacial deposits exposed in these excavations are of two kinds, boulder clay and sand. The boulder clay consists of a stiff, reddish-brown, quartzose clay matrix, with the usual boulders varying in size from gravel to masses of several cubic feet content scattered irregularly through it. From a special investigation carried out by Mr. Tyrrell, the clay matrix was found to consist of a quartz flour stained reddish-brown by a surface coating of iron oxide on each of its minute, angular particles. These particles average 0·007 mm. diameter, and the matrix contained a certain proportion of large particles which had not been reduced by the general attrition below the dimensions to which the name sand is applied. The proportion of large to small particles varies throughout the matrix, which varies, consequently, from a pure clay to a pure sand. When treated with dilute hydrochloric acid the colouring matter is removed from the surface of the minute particles, leaving them white and glistening under the microscope. In addition to the quartz flour, which constitutes the bulk of the matrix, there is about 2 per cent. of calcium carbonate and other related salts. These are, of course, to be expected in consequence of the thin cement-stone outcrop amongst the sandstones, the attrition of which has provided the materials of the boulder clay. Mr. Tyrrell made careful examination of the matrix as to solubility, but found that, under the conditions of the experiment, only about $\frac{1}{5}$th per cent. of the bulk was soluble in water.

The boulder contents of the clay are chiefly of sandstone, the outcrops of which lie immediately to the north of the area; and whilst small blocks of granite, schists, and gneiss occur, they

Digitized by Google

are few in number. These facts support the already well-established conclusion that the boulder clay is mainly derived from the underlying strata or from those in the immediate neighbourhood.

The sand associated with the boulder clay is, as stated above, an almost purely quartzose sand stained reddish-brown by iron oxide, and occurs in beds and lenticular masses near the surface of the clay. It is generally very fine in texture, but in one or two pockets passes through a coarse sand into a gravel.

In his paper in the first volume of these *Transactions*, Sir A. Geikie has made a division of glacial deposits into three groups, according to phenomena met with in the deposits, which he attributes to—

(1) The old and general glaciation of the country.
(2) The marine submergence and re-elevation.
(3) The final disappearance of the ice.

The characteristics of the deposits in this area seem to place them in the first and last of these groups, any evidence as to any of the deposits belonging to the period of marine submergence and re-elevation being entirely wanting. No fossils or shells of any kind have been found, and the nature and structure of any of the deposits we have examined did not suggest to us littoral or marine origin. The present elevation of the deposits described is from 600-850 feet above mean sea-level, and, although evidence has been obtained in other parts of the country to show that places now standing higher than that were submerged during the Glacial period, we have found no trace of such a submergence here. It is possible, of course, that loose, uncompacted beds of shells and gravel which constitute elsewhere the evidences of marine submergence and re-elevation have been removed from this area by atmospheric denudation.

The boulder clay found in this neighbourhood belongs undoubtedly to the period of general glaciation, whilst the sand and gravel beds found at the eastern extremity of the area, in the neighbourhood of the Drymen road, present appearances characteristic of the third period or that of the disappearance of the ice, when the all-enveloping sheet of the general glaciation gave way to small, isolated valley glaciers. It is only

Digitized by Google

below a level, roughly about 700 feet above sea-level, that such deposits are found. Although sand and gravel beds are found in the boulder clay in the puddle trench excavations, they belong to a different category, and seem to us to have resulted from the washing out of the finer clay matrix by waters running under the ice sheet. On the road of access and on the pipe track, up to a level, roughly about 700 feet above sea-level, the deposits cut through are gravel, sand, and sandy clay, resting in that order on a sheet of pure boulder clay; but above that level, in both series of excavations, and also in the excavations in the reservoir neighbourhood, which lie above 750 feet O.S., gravel and sand occur only in small patches and pockets in the clay itself, and appear to us to be satisfactorily accounted for by the above explanation.

In addition to the nature and structure of the deposits themselves, the whole appearance of the parts of the area above and below the 700-feet contour line confirms the above conclusion. Above the 700-feet line, and looking southwards, the country still presents a smoothed and rounded appearance, with flowing outlines characteristic of the passage southward, over it of the widespread sheet of land ice described by Geikie as descending from the Highlands into the low grounds of Forfar, Perth, Stirling, and Dumbarton. The stream would abut against and overflow the chain of the Kilpatricks, the Campsies, and the Ochils, forcing its way through all the transverse valleys of these uplands into the low grounds to the south. It was under this widespreading sheet that the boulder clay was formed. Below the 700-feet contour line, on the other hand, the hummocky appearance of the surface at once suggests a deposit of morainic materials, such as would be left behind by a number of small valley glaciers.

At the puddle trench, where the clay was stripped from the surface of the rock, the latter was found to be beautifully striated. The boulder clay, when cut through, was found with its lower surface hard down against the surface of the rock, with its striating agents, the pebbles and gravel, held firmly down on the rock surface, just as they had been when the glacial motion finally ceased. The striations on the rock surface run in a N.W.-S.E. direction, but, as this is the direc-

Digitized by Google

tion of the valley at this point, it cannot be taken as indicating the general direction of flow of the ice sheet. Two sets of striations are actually to be found in places on the surface of the rock, but these may be due to an eddying or local motion in the ice sheet.

No large erratics have been found by us in the area described, and, although the dip slope of the Auchineden escarpment is strewn with boulders, we are of opinion, judging from the position and nature of the boulders, that these represent what remains of the sheet of boulder clay which once enveloped this part of the country also, but has now been removed by atmospheric denudation.

The elliptically shaped knoll referred to earlier in these notes merits further notice. The shape, the position, and the bearing of the major axis of this hill, as well as the materials which form it, mark it out as of quite different origin from the knolls already referred to which lie at the eastern side of the area. These latter knolls are typically morainic, and probably resemble somewhat in origin and character the Kames of Carstairs and the morainic knolls of the Drumchapel and Duntocher districts. The features of the knoll in the reservoir area, however, at once suggest a shaping agency other than that of ordinary atmospheric denudation. The authors are of opinion that the height of this hill gives some indication of what must originally have been the thickness of the blanket of boulder clay here, and that the present shape of the hill has been roughly carved out by small valley glaciers during the retreat of the ice.

The upper part of Burn Crooks, above the East Corner (see Fig. 4) is a direct continuation of the upper valley of the Auldmurroch Burn, one of the head-waters of the Allander, which flows into the Kelvin. Burn Crooks, doubtless, once discharged in this direction, but has been beheaded by the Finnich Burn; which, owing to its shorter course and greater gradient, has been enabled to cut back rapidly through the sandstones and the Knockvadie sill, thus capturing the head-waters of the Auldmurroch Burn. This diversion may have been initiated or facilitated by glacial damming.

It is interesting to note that the reservoir site is placed upon

Digitized by Google

the boundary line of two different topographies. Upstream of the trench there is a typical old valley, with a broad, flat, alluvial bottom and concave sides, in which Burn Crooks meanders slowly at a temporary base-level conditioned by the slow erosion of the hard Knockvadie sill. Below this point, on the other hand, the stream has a rapid fall, and it is actively engaged in deepening and widening its valley. Its course thus presents all the features of a young topography—a deep, narrow gorge, vertical-sided in some places and typically V-shaped in others.

EXPLANATION OF PLATE.

Fig. 1.—The Whangie, from the north.

The deep and narrow cleft is seen on the left-hand side. The figure of the man above gives the scale.

Fig. 2.—Volcanic "necks" near the Whangie, looking north.

In the foreground are the lava terraces and escarpments, which are pierced by two small "necks," seen on the left hand; whilst a third neck, the Whangie hill, is seen on the extreme right hand.

Digitized by Google

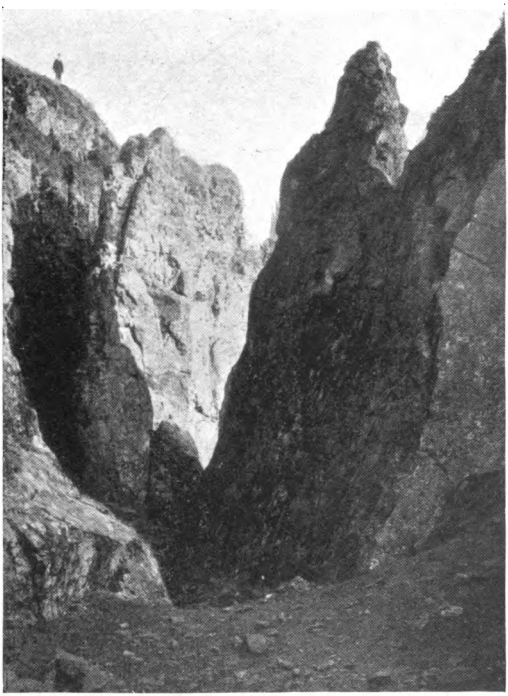


Fig. 1.—The Whangie, from the North.

Fig. 2.—"Necks," near the Whangie, looking North.

Digitized by Google

Digitized by Google

No. XXVIII.—The Petrology of the Auchineden District,[1] Kilpatrick Hills. By G. W. Tyrrell, A.R.C.Sc., Assistant in Geology, Glasgow University.

[Read 13th May, 1909.]

The general geology of this district has been described in the foregoing paper. The igneous petrology will now be described. The rocks will be taken in the following order:—

I. Fragmental rocks of the vents.
II. The intrusions in the vents.
III. The lavas of Auchineden Hill.
IV. The E.-W. dyke.

I. Fragmental Rocks of the Vents.

These vary from coarse, pebbly agglomerates composed of fragments of lavas and sandstones to fine-grained grey, green, purplish, or red-coloured tuffs. It will be sufficient as a typical example to describe the material filling the Little Caldon neck. This is a medium-grained variety which in thin section is seen to consist of fragments of porphyritic olivine basalt lava, large detached crystals of serpentinised olivine, and abundant detrital quartz, mostly well rounded, but occasionally angular and subangular. There are also a few broken crystals of fresh orthoclase. Both the latter constituents are obviously derived from the adjacent sandstones. In another slide of the same rock occur fragments of yellow, partially hornfelsed shale, and pieces of another type of lava, very fine grained and porphyritic with felspar, not olivine.

A thin section of a tuff from the Knockvadie neck shows a compact groundmass of magnetite, containing scattered laths of plagioclase, numerous rounded areas filled with calcite, and occasional grains of quartz derived from the adjacent sandstones.

[1] This work has been done with the aid of a Research Grant from the Carnegie Trust for the Universities of Scotland.

Digitized by Google

II. The Intrusions in the Vents.

Few of the vents are composed entirely of ash. The majority have been invaded by irregular basaltic intrusions. Some of the vents contain no fragmental material at all, but are sealed by a plug or boss of basalt.

Petrologically these intrusions are very uniform in type. They are all olivine basalts, usually compact and fresh, rarely porphyritic. Megascopically they are compact black or bluish rocks, lustrous on a freshly fractured surface, with an occasional small phenocryst of olivine and felspar. They weather sometimes rather deeply with a buff or pinkish crust. This, together with the fact that the felspars of the groundmass frequently have a fluidal arrangement, has led to these rocks being described as trachytes and andesites by some observers. When weathered in this fashion the fractured surface has a greasy or resinous lustre. The specific gravity of the fresh rock varies from 2·80 to 2·895. Microscopically these rocks are composed of a groundmass of plagioclase, augite, and magnetite, with more or less abundant small phenocrysts of olivine and plagioclase, never augite. The structure is generally ophitic, less frequently intersertal. The rocks of the different vents, although answering to the above general description, have each some slight peculiarities, which are described in the following paragraphs:—

Knockvadie Intrusion.—Fresh material is easily obtainable in the crags on either side of Burn Crooks, and in the puddle trench now being excavated in that locality. It is a lustrous, black, fine-grained rock, composed of numerous plates of purplish augite ophitically enclosing great numbers of small laths of plagioclase felspar. Small crystals of idiomorphic magnetite and microporphyritic olivine, the latter usually completely altered to brown and green serpentine, are abundant. The felspar occurs as small laths ophitically enclosed in the augite, or forming a groundmass with magnetite and olivine; but there are also a few small phenocrysts, glassy and beautifully zonal, in which extinction angles up to 21° were obtained in albite twin lamellæ. This indicates a composition Ab_1An_1—an acid labradorite. In the larger crystals well-developed pericline lamellation also occurs. The rock is quite holo-

Digitized by Google

crystalline, there being no trace of cryptocrystalline or glassy matter. It is an olivine basalt or dolerite closely approaching the Jedburgh type of Watts,[2] but the structure is thoroughly ophitic, not subophitic. The felspars are of a comparatively acid variety. This is characteristic of many types of Scottish Carboniferous lavas, including the mugearites and Markle basalts.

Quite a distinct variety of this rock occurs in a deep bore on the site of the trench, at a depth of 144 feet. In this variety the main mass of the rock consists of crowded felspar laths, between which are wedged rows of small granules of augite and magnetite, usually single, like strings of beads. Ophitic structure is entirely absent. Olivine occurs as small micro-porphyritic crystals, usually completely serpentinised. There are one or two porphyritic felspars containing inclusions of augite and magnetite. The specific gravity of this variety is 2·87, whilst that of the ophitic variety above described is 2·88.

As described in the former part of this paper, a band of soft, decomposed, vesicular rock occurs in the trench, which is believed to mark the site of a Carboniferous fumarole. In thin section, whilst the structure remains essentially the same as that of the fresh rock, all the minerals have undergone an extreme alteration, and amygdules of calcite and "green earth" have been introduced. The felspars, although retaining their forms, are thoroughly kaolinised, but the femic minerals, with the exception of magnetite, have entirely disappeared, leaving an aggregate of calcite and secondary magnetite. In another slide the magnetite occurs abundantly in small granules, so closely crowded together that it forms almost a continuous groundmass. The rock is thoroughly vesicular, the cavities being filled with calcite and the soft, amorphous, secondary products usually included under the term "green earth." The change from fresh olivine basalt to this intensely altered rock takes place quite gradually, although within a short distance. It is just such an alteration as might be expected to take place in the vicinity of a fissure from which steam and heated waters were issuing.

The lava plug of the *Cathythirsty* neck on Quinloch Muir is

[2] In Sir A. Geikie's "Ancient Volcanoes of Great Britain," vol. i., p. 418.

Digitized by Google

composed of long, lathy felspars showing fluidal structure, to a large extent enclosed in small, elongated plates of slightly pleochroic purple augite. Magnetite is abundant in small, irregular granules, for the most part enclosed in felspars. Olivine occurs in sparse microporphyritic crystals, idiomorphic, and completely serpentinised. A few fairly large porphyritic felspars occur. The maximum extinction angle obtainable in albite twin lamellæ is as low as $10\frac{1}{2}°$, indicating a composition $Ab_2\ An_1$—andesine. Under a high-power objective the rock is seen to be charged with numerous minute, highly refractive needles, probably of apatite. The specific gravity is 2·80. The neighbouring neck, a little to the east of Cathythirsty, is composed of a very similar rock. It is, however, much fresher than the Cathythirsty plug. The olivines are quite fresh, or at most with incipient serpentinisation. The felspars of the groundmass do not show fluidal structure. There are a few squarish microporphyritic sections of glassy plagioclase, sometimes untwinned and then finely zoned.[3] The maximum extinction angle obtainable is $16\frac{1}{2}°$, indicating an andesine of composition $Ab_5\ An_3$. The rock is an ophitic olivine basalt approaching the Jedburgh type.

The intrusion into the agglomerate of the *Little Caldon* neck is of the same type as the two preceding rocks, but differs slightly in not being quite holocrystalline. It contains a fair amount of a brownish glassy material in the groundmass, filling the interstices between the other constituents. This rock has been analysed by E. G. Radley, of the Geological Survey.[4] Its specific gravity is 2·895.

III. The Lavas of Auchineden Hill.

From the base, near the Whangie, at the north-western extremity of the hill, to the last well-preserved terrace at Auchineden Wood, there are fourteen distinct flows, which have been numbered A1 to A14 in ascending order. Excluding A8, a sudden thick intercalation between A7 and A9 cut through by the new road, and which does not appear in the direct traverse, there is a distinct but slight increase of basicity from

[3] Sections parallel to 010. Idding's "Rock Minerals" (1906), p. 229.

[4] Summ. *Prog. Geol. Sur.* for 1907, p. 55.

Digitized by Google

A1 to A14, as evidenced by microscopic examination and by the specific gravities—

	Sp. Gr.
A_1, - - - - - -	2·80
A_3, - - - - - -	2·83
(A_8), - - - - - -	(2·98)
A_9, - - - - - -	2·84
A_{14}, - - - - - -	2·86

Megascopically A1 to A7 are compact non-porphyritic or sparingly porphyritic lavas, weathering deeply with a buff or pinkish crust. On breaking a large block the fresh rock is bluish in colour. A fluidal structure is often apparent on a weathered surface. This fact, together with the greasy appearance and the prevalent light colour, has led to these rocks being termed trachytes and andesites. In our field notes, before microscopic examination, the rocks were called " blue-hearted trachytes."

In thin section A1, which is fairly typical of the three lower flows, is seen to consist of laths of plagioclase enclosed ophitically in small plates of purplish augite. There is also abundant granular magnetite and sparse serpentinised olivine. In this slide there is one large phenocryst of plagioclase cut exactly perpendicular to the albite lamellation, and enclosing a crystal of olivine. It gives an extinction angle of 13°, indicating an andesine of composition Ab_5An_3. The rock is thus similar to the prevailing variety in the vents.

A2 shows olivine altered to a highly pleochroic mineral of micaceous habit (? iddingsite). A3 contains microporphyritic felspars crowded with inclusions of magnetite and augite, and irregular vesicles partly filled with vermicular " green earth " and hæmatite. On the N. flank of Auchineden Hill an intercalation of a type highly porphyritic with felspar and serpentinised olivine occurs between A3 and A4.

A4, an extensive flow traceable right round the north and west sides of the hill, is an intersertal variety, consisting of plagioclase laths, with interstitial granular augite and magnetite, sparse porphyritic felspars full of inclusions, and microporphyritic olivine. The maximum extinction angle of plagioclase is 14°. Pericline twinning is fairly abundant. A5 is a similar rock. A6 and A7 are returns to the ophitic type.

A8 is an abnormally basic variety intercalated between A7 and A9 on the S. side of the hill. In hand-specimens it is a

Digitized by Google

dense black rock containing abundant phenocrysts of glassy plagioclase and leek-green olivine. Microscopically it is seen to consist of an extremely fine-grained and densely crowded groundmass of granular augite and magnetite, with much less abundant plagioclase. In this are embedded numerous idiomorphic microporphyritic phenocrysts of glassy plagioclase very uniform in size. Finally, there is a much larger, less abundant third set of plagioclase phenocrysts, and also large porphyritic and serpentinised olivines. The third generation of plagioclase phenocrysts is that visible in the hand-specimen. Some contain zonally arranged inclusions of groundmass; others are corroded by, and contain inlets of, the groundmass. The maximum extinction angle is 28°, indicating a medium labradorite of composition Ab_2An_3. This rock corresponds closely to the Kippie Law type of Watts.[5] Its occurrence as a sudden, short, and thick intercalation, and its abnormally basic composition render it probable that it is an intrusion belonging to a set of similar intrusions which occur on or about the same horizon throughout the Kilpatrick Hills.

A9 is an intersertal variety similar to A4 and A5. A10 to A13 belong to the ophitic type. A14, whilst generally similar to the other intersertal types, presents a somewhat different facies owing to the incoming of porphyritic augite. The groundmass consists of lathy plagioclase, with granulitic augite and magnetite. The phenocrysts, consisting of plagioclase, olivine, and less abundant augite, are fairly large and numerous. The augite is purplish in colour, idiomorphic, and zoned by inclusions round the margins. The iron ore in this rock is partly titaniferous, as it can be seen in process of alteration to leucoxene and sphene.

IV. The E.-W. Dyke.

This is a medium-grained, greyish rock, weathering into cuboidal blocks with rounded edges and corners. Microscopically it is seen to consist of fairly fresh plagioclase laths penetrating a brownish-green serpentinous substance which, no doubt, represents original augite. Magnetite is abundant in small idiomorphic crystals, and ilmenite in dense, grating-like

[5] Sir A. Geikie, "Ancient Volcanoes," vol. i., p. 418.

Digitized by Google

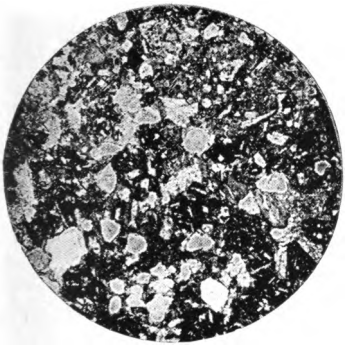


Fig. 1.

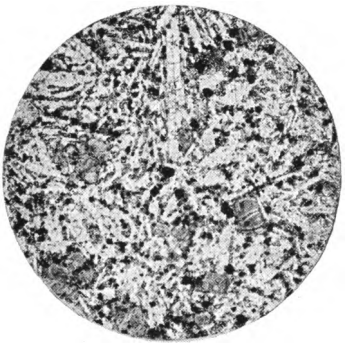


Fig. 2.

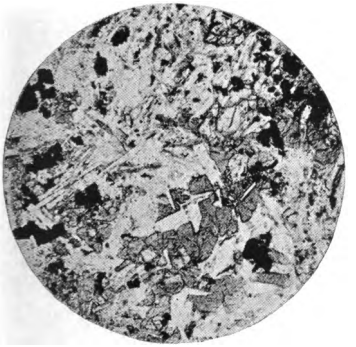


Fig. 3.

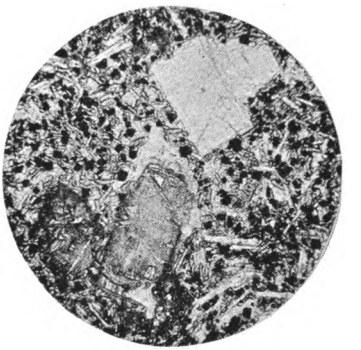


Fig. 4.

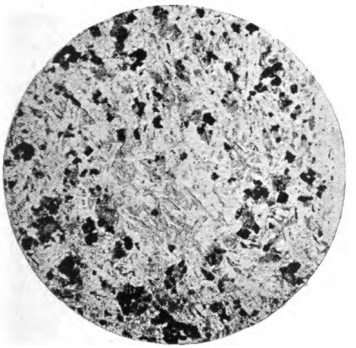


Fig. 5.

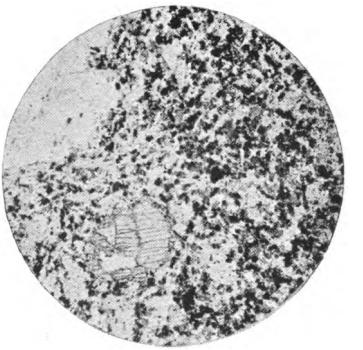


Fig. 6.

Micro-photographs of Rocks from the Auchineden District, Kilpatrick Hills.

Digitized by Google

Digitized by Google

skeletal aggregates of rods, either crossing in two directions at right angles or in three, at an angular distance of 120°. A dense, brownish, cryptocrystalline substance occupies the interspaces, sometimes also quartz.

This rock is a quartz-diabase of the same type as the other E.-W. dykes, and their accompanying protrusions in the Midland Valley of Scotland.

EXPLANATION OF PLATE.

Fig. 1.—Agglomerate, Little Caldon, Stockiemuir. Ord. light, × 11.

Angular fragments of quartz, with large pieces of vesicular lavas, in a paste made up of the minerals usually present in the lavas of the district and their alteration products, *i.e.*, plagioclase, augite, olivine, serpentine, magnetite, and calcite. Two fragments of orthoclase, derived together with quartz from the adjacent sandstones, can be seen at the top of the field.

Fig. 2.—Olivine basalt, intrusion in Knockvadie vent, from diamond drill boring at depth 144 feet. Ord. light, × 21.

Microporphyritic plagioclase and olivine (serpentinised) in a groundmass of plagioclase, augite, and magnetite. The granules of augite and iron ore are wedged between the felspar laths in single rows, like strings of beads. This structure is well seen in the top left-hand corner of the field.

Fig. 3.—Ophitic olivine basalt, dyke-like protrusion from small "neck," a little east of Cathythirsty, Drymen road. Ord. light, × 21.

The field shows plagioclase and augite in ophitic relations, with small crystals of olivine and magnetite. Olivine can be seen at the top right-hand corner of the field, and also enclosed in the large plate of ophitic augite below the centre.

Fig. 4.—Olivine basalt, from a probable intrusion between A_7 and A_9 lavas, road of access to Burn Crooks Waterworks, Auchineden Hill. Ord. light, × 46.

A very basic rock consisting of a dense groundmass in which augite and iron ores are predominant over the plagioclase. Numerous phenocrysts of idiomorphic plagioclase and serpentinised olivine, but not augite, are present.

Fig. 5.—Ophitic olivine basalt, first lava flow, near the "Whangie," Auchineden Hill. Ord. light, × 21.

Plagioclase and augite in ophitic relations, with numerous small crystals of magnetite and serpentinised olivine. Resembles Fig. 3 very closely.

Fig. 6.—Olivine basalt, lava flow No. 14, south-eastern escarpments of Auchineden Hill. Ord. light, × 21.

Dense groundmass of plagioclase (white), iron ores (black), serpentinised olivine (cloudy areas), and augite (minute highly-refracting granules). Phenocrysts of plagioclase and augite. This flow is the first of a new set of lavas, in which augite is a prominent porphyritic constituent.

Digitized by Google

No. XXIX.—The Economic and Petrographic Geology of the New Red Sandstones of the South and West of Scotland.

By Robert Boyle, B.Sc., A.G.T.C., President of Glasgow University Geological Society.

[Read 27th May, 1909.]

I. Introduction.

There are in the South and West of Scotland eight separate areas of some considerable extent occupied by red sandstones of post-Carboniferous date. Six of these areas have been economically developed. That they are younger than the Coal Measure sandstones is certain, but they have been variously regarded as of Permian or Triassic age. Whatever their age may be, their characteristics are very similar, and they will here be referred to as "New Red Sandstones." The various districts may be separately distinguished as—(1) Arran, (2) Mauchline Basin, (3) Thornhill Basin, (4) Dumfries Basin, (5) Annan Basin, (6) Lochmaben and Corncockle Moor, (7) Moffat, (8) Ballantrae. They consist of bright brick-red, red, or orange-red sandstones, with abundant false bedding, associated with more or less volcanic material at their base. They will be referred to in the order given. There seems good reason to believe that they were originally all connected, their subsequent isolation being due to subærial denudation. Goodchild (*Trans. Geol. Soc. of Glasgow*, vol. xi., part i., page 96—"Desert Conditions in Britain") considers that the new red rocks, and even the younger Jurassic rocks, formerly covered nearly the whole of Britain; and Sir A. Geikie ("Scenery of Scotland") mentions the discovery of fossils belonging to the *Avicula contorta* zone of the Rhætic group as indicating that the Arran sandstones and marls belong to the Triassic period. He further says that these strata no doubt at one time extended over a much wider area of the Midland valley. A discovery by Messrs. Peach and Gunn of fragments of material, sealed in a volcanic neck, belonging to

Digitized by Google

the Rhætic and Lower Lias shales, and of hard, white limestone with Cretaceous foraminifera, shows that the Trias, Lower Lias, and Chalk once stretched over the region of the Clyde. The objections to considering the New Red Sandstone series of Mauchline to be of Triassic age are—(*a*) They form one continuous series with the Coal Measures; (*b*) they are associated with considerable contemporaneous volcanic action, which is unknown elsewhere in the British or German Trias. The same holds good to a large extent in the north part of the Thornhill area, and in its prolongation along the Carron water valley. As will afterwards be shown, there is a general similarity amongst all these rocks, except in the Annan area, which would indicate that they were of the same age, or at least formed in periods which were climatically the same, and without any break. On the whole the age seems more likely to be Permian.

It is mainly the areas of economic importance which will be dealt with. There are, in addition, scattered patches of red breccias and sandstones in the valleys of Nithsdale and Annandale, in a little basin among the Leadhills and in Loch Ryan, Wigtownshire, which are either of Permian or Triassic age. These seem to point to the original large extent of area covered by these deposits and the great amount of denudation which has taken place.

II. General Descriptions of Areas.

1. *Arran.*—In 1894 it was first observed that the red rocks of the south of Arran were unconformable to the underlying Carboniferous beds. The lower sandstones resemble those at Mauchline, and are extremely false bedded. The thickness is about 1000 feet, being about one-half of those beds supposed to belong to the Lower Trias. The lowest subdivision of this series is well represented between Corrie and Brodick Castle. The sandstone contains ridges of hardened joints, crushes, and faults, and occasionally many branching veins of hardened material, which cause the rock to weather with a honeycomb structure. The ridges are supposed to be due to igneous action, perhaps that of dykes beneath the present surface. The colour is a characteristic bright brick-red, and there is much

Digitized by Google

false bedding. The outlier at the Cock of Arran, in the north of the island, is similar to the Corrie rock. It occupies an area of about $\frac{5}{8}$ of a square mile, and the formation rises to about 1000 feet above sea-level. There are beds of conglomerate overlying it, and bands of the same material at its base. Areas of the New Red Sandstone are scattered all over the island. Besides the whole eastern shore south of Corrie, it is found as far west as Gleann Dubh, where fine crags have been formed, and also well up Benlister Glen. On the west side of the island it is found along the coast south of Auchagallan, and it spreads over the vale of Shiskine on either side of the mouth of the Machrie Water. Near the latter there are many cavities of various shapes and sizes in the sandstone, known as "moss holes." The various districts are very fully described in the Arran Memoir of the Geological Survey.

Although the possibilities of the island are very great, quarries have only been opened at Corrie and Brodick Wood, at the back of the school. "Whin" is being quarried for road metal right in the middle of the Corrie quarries, and the sandstone has included in it elongated pieces of very hard rock, accompanying what are known as "moss patches," which may be as large as 18 inches to 2 feet. These portions are dark in colour, and are probably hardened, due to an excess of carbonates in the sand produced by segregation. The top decomposed rock, variously called "bare," "tirr," and "strip," is about 4 feet. The quality appreciably improves with the depth, but the small, black carbon spots, common to most red rocks, become more numerous. The greatest depth worked is about 70 or 80 feet. False bedding is very abundant, and an angle of 40 degrees is not uncommon. There are numerous thin, hard, ramifying bands in the rock, locally known as "glass bands," from the thickness of a thread up to $\frac{1}{2}$ inch or more. They appear to be of a calcareous nature, and are probably due to deposition from solutions. Igneous action may in some cases have had to do with their origin. They spoil the rock considerably for working. The quarries at Corrie have been closed for about fourteen months, but Corrie rock is the principal building stone in Arran. Fairly large blocks can be obtained. The grain is rather coarser than most

Digitized by Google

of the New Red Sandstones, but the texture is very uniform. It is soft and easily worked, and hardens by exposure to the air. It is softer than Locharbriggs rock. Much of the stone is shipped, a good deal of it coming to Ayrshire and the Clyde district. Troon harbour is said to have been built of rock from the northern quarry. The School of Art and Simpson's warehouse in Glasgow have been built of Corrie stone.

2. *Mauchline Basin.*—The New Red Sandstones in Ayrshire occupy an area of about 18 square miles. The outline is pear-shaped, and extends from Mauchline westwards to near Tarbolton, and southwards as far as Trabboch Burn. They are encircled by a ring of volcanic rocks, which form a rim to the basin, varying from ½ to 1½ miles wide. This igneous rock consists of porphyrite, melaphyre, and tuff, and dips down underneath the sandstones. Volcanic necks which belong to the same period of activity occur scattered through Ayrshire and Nithsdale, in Dumfriesshire, as, for example, at Sorn Hill, Stevenston near Ochiltree, Whitehill near New Cumnock, and at Blackeddie, Crawick Bridge, and the district north of Sanquhar. Beneath these igneous rocks comes the Coal Measure series, consisting of red sandstones, shales, and seams of coal; and in all probability there is a large area of workable coal several hundred fathoms beneath the surface in the Mauchline area. It may be affected in many places by volcanic action and burning due to intrusions in the same and later periods. Some of the necks may, indeed, be covered over with the sandstone and thereby hidden, as the volcanic activity seems to have ceased largely before the formation of the sandstone had proceeded very far. From recent investigations by Mr. D. Ferguson, F.R.G.S., M.Inst.M.E., described in a paper read before Glasgow University Geological Society, there can be little doubt that this is one of the great sources of coal in the near future. Its probable existence was pointed out as far back as 1879 by Sir A. Geikie before the Royal Commission on Coal. The upper seams beneath the centre of the basin would appear to be at a depth of approximately 400 fathoms, and underlying the Upper Red Sandstones of the Carboniferous, which again underlie the melaphyres and New

Digitized by Google

Red Sandstones of Mauchline district. The area now occupied by the latter has, near the close of the volcanic period, been occupied by a lake of considerable depth, in which current action was very marked. In this were deposited the beds of bright brick-red or orange-red sandstones, which are so characterised by abundant false bedding. In places the melaphyre can be seen intercalated with the sandstone, as on the right bank of the river Ayr, between Howford Bridge and Ballochmyle viaduct. The cliff section here measures 56 feet of sandstone resting on 16 feet of sandstone hardened into quartzite, where the melaphyre and tuff are intercalated. There are five bands of intruded rock alternating with four of the hardened sandstone. The thicknesses vary from 3 feet to 1 foot. There is also about 20 feet more of irregular decomposed sandstone on the top, giving a total cliff depth of about 92 feet to the river bed. On the left bank, a short distance above this, is a section showing 55 feet of sandstone resting on 29 feet 6 inches of melaphyre, containing numerous amygdaloids of calcite and steatite. The felspars in it are reddish brown, being considerably iron-stained. Immediately below this is the great Ballochmyle stone viaduct carrying the Glasgow & S.-W. Railway over the Water of Ayr, with a central arch, which is one of the largest in the world. It springs from precipitous rocks on each side, has a clear span of 180 feet, and is 157 feet 4 inches above the river to the highest point of the centring. The red sandstone of which it is built was quarried at the site, and in founding the north abutment, the cave, or rock hiding-place of Alexander Peden, prophet and Covenanter, had to be destroyed. Further up, just past where the Lugar Water joins the Ayr Water, is Barskimming Bridge. It is a one-arch structure, also most beautifully situated, and was recently rebuilt of the red sandstone. The left bank below the bridge shows the false bedding very well, but here the rock is more flaggy. All round this district the soil, especially as seen in a ploughed field, has a distinctive deep red colour, derived from the decomposition of the underlying red sandstone.

Excellent sections have also been cut by the Lugar Water between Ochiltree and Barskimming, especially near the old,

Digitized by Google

picturesque castle of Auchinleck, perched on a high knoll on the right bank, where the Dippol Burn enters the Lugar, thus securing protection on two sides. The walls, several feet in thickness, are built of the red rock, and set in mortar, which is as hard and binding as it was seven hundred years ago. There, indeed, is an excellent testimony to good building and to the weathering qualities of the red sandstone. In spite of ages of atmospheric attack on its historic and venerable walls, the stronghold of its weathering capacity has remained comparatively secure. Lines and furrows, caused by the continual worry of storm and wind, have beautified its expression and revealed to the scientific eye the peculiar and varied nature of the false bedding which distinguishes this sandstone. A few feet of the melaphyre can be seen at the base of the sandstone on the opposite side of the gorge, which is probably 100 feet deep. The Dippol Burn for about half a mile traverses a narrow gorge, averaging about 35 feet in depth, in rather thin, flaggy, false-bedded, brick-red sandstones.

The scenery in the districts described is of the highest order, especially along the rivers and streams, and it is noteworthy that much of Burns' finest work was produced in the area occupied by these new red rocks.

Several quarries have been opened in the New Red Sandstone—at Mauchline, Barskimming, and Failford. At Mauchline there are three quarries, owned by Mr. Marcus Bain, one of which, the west one, is being worked. The maximum depth attained so far is about 210 feet, though operations have mostly been confined recently to about 189 feet in the west quarry. The rock varies from a hard compact variety, suitable for making grindstones, to a soft, friable rock. Several beds of it are much in request for grindstones, which have been used by the Clyde shipbuilding yards for many years. They are also sent for the Burmah railways. The colour is bright brick-red or orange-red, at once distinguishing it from the underlying brown, grey, or white sandstones of the Coal Measure series, quarried at Auchinleck and Skares. There is much false bedding, but the strata are, in the main, fairly horizontal; in adjacent parts of the quarry, however, the beds may be nearly level, and almost so steep

Digitized by Google

as to require ladders for working them. This does not seriously interfere with the supply of large blocks. There is no direct faulting in the rock, but there are corners of inferior material, as in most quarries, and an irregular track of soft, useless material may run for some distance through them. The small black carbon spots are not much met with here. A remarkable slab was found in the quarries some years ago showing exceptionally fine dendritic markings. It is now exhibited in the Dick Institute, Kilmarnock. The size is about 4 feet 2 inches by 1 foot 10 inches by 7 inches thick, and the tree-like impressions occupy practically the whole of it. It was at first supposed to be a fossil fern, but close examination leaves no doubt as to its being due merely to the arborescent deposit of earthy manganese oxide, which not infrequently appears between the joints of fine-grained rocks, in plant-like forms. There are two main stems in the centre of the dendrite, separated about 3 inches, along which the main solutions appear to have worked, throwing out numerous branches and twigs on each side. These manganese oxides are often found to exist with the oxides of iron in a rock. They are liable to be deposited as bog manganese, just as bog iron is deposited, and under similar conditions. The rock is easy to work, and is rather open and fairly coarse grained on the average. Large quantities are sent to Glasgow. It will be useful in this case, as in those to follow, to give a list of some buildings of the stone described, with date of erection. This will enable observations of the weathering properties of each to be taken *in situ*, both in city and country atmospheres:—

Citizen Offices, Glasgow, -	1886	Buchanan Retreat, Bearsden, -	1888
Hyndland Church, ,, -	1885	Burns' Monument, Kilmarnock,	1881
Camlachie Halls, ,, -	1889	The Academy, Kilmarnock, -	—
Allan Glen's (South Extension), Glasgow, - - -	1888	New Bridge, Ayr, - - -	—
		New Hospital, Ayr, - -	—
Children's Hospital and Dispensary, Glasgow, - -	1887	Lynedoch Railway Station, Greenock, - - - -	1884
Barony Church, Glasgow, -	1888	Spiers' School, Beith, - -	1887
British Linen Bank, Clydebank, - - - - -	1887	New Railway Station, Paisley,	1888
		Greenlaw Church, Paisley, -	1888

It has also been used for many miles of tenements in Glasgow. Most of the buildings have been erected during the last twenty

Digitized by Google

years, so that the stone has not yet had a long enough test, though standing very well so far.

A quarry is also worked by Messrs. Baird & Stevenson at Barskimming, about 1 mile away from Ballochmyle. The surface and working level there are lower than at Mauchline, and pumping has had to be resorted to almost continuously to keep down the water. The rock is very similar to that at Ballochmyle. In the Glasgow district Barskimming stone has been mostly used for tenements.

At Failford, near the western edge of the basin, and about 3 miles west of Mauchline, quarrying was carried on for some time beside the river Ayr. The quality, however, seems to have been unsatisfactory. From the débris it appears to have been rather poor in many places and thinly bedded. There is, however, still a large store of good rock in the Mauchline basin. Extensions are at present contemplated at Ballochmyle quarries. The amount of "tirr" or surface baring is not much over 6 feet there on the average.

3. *Thornhill Basin.*—This basin is essentially a hollow in the Silurian hills which has been filled up with later strata. The valley of the Nith, like that of the Annan, is an ancient hollow covered up with deposits of the Coal Measure and succeeding period. These have, in many places, been subject to very extensive denudation, so that the Nith now flows, for much of its course, in an old Silurian valley. In the vicinity of this area there are small detached basins, probably originally connected with the main area. Two of these lie a little to the east, in Closeburn parish. There is also a small detached area at the extreme north. It is separated from the main basin by the volcanic rocks of the same series a little beyond Carronbridge station. This part contains a considerable amount of intercalated volcanic material. The main area is about 11 miles long, and contains about 22 square miles, the greatest width being about 5 miles. Thornhill is situated near the centre. The sandstone is associated with red shales and clays at the top, and volcanic débris and red tuff at the bottom. As in the case of Mauchline, the beds of porphyrite and tuff at the base are intercalated with the red sandstone. They may be scattered irregularly through the sandstone or

Digitized by Google

aggregated into distinct lenticular seams. The junction of the Permian series with the Lower Coal Measure sandstones is well exposed on the right bank of the Crichope, just below Burley's Leap. Further south, however, the red rocks rest directly on the Carboniferous or Silurian strata, and the igneous zone is wanting. Where the latter does occur it is very similar to that in Ayrshire. It varies from coarse, earthy amygdaloidal rock to a purple or dull reddish porphyrite, consisting essentially of rather decomposed plagioclase felspar and hæmatite, usually irregular in form. A description of it is given in the Memoir to Sheet 9. The volcanic activity which gave rise to these lavas must have been very great, but appears to have ceased after the formation of the lower beds of sandstone. There are sections on the Nith showing these igneous rocks nearly as far as Nithbank. Volcanic lapilli, dust, and bombs may be seen at several exposures, for example, on the Cample Water, near Gatelawbridge, where a small stream and waterfall have cut through a high bank a short distance above Kettleton Bridge. Carboniferous shales and sandstones are here overlaid by lava containing thin bands of sandstone with lapilli. It is rather remarkable that there is no definite volcanic neck to account for the prolonged action which must have taken place. The included fragments have all the appearance of ejected material. There are four necks supposed to be of Permian age between Sanquhar and Kirkconnel, the Crawick Bridge, on the main road to Carlisle, being founded on one, and the farmhouse of Blackeddie built on another. The craters responsible for the igneous material in the northern half of this area may have been ultimately covered over with sandstone.

The typical red sandstone scenery is as well developed here as in Ayrshire. The stupendous nature of the denudation within recent times is shown in the Crichope gorge, which is over 56 feet deep at "Burley's Loup," and the width is no more than about 6 feet in places. In the deepest parts the gully is nearly 90 feet deep.

The sandstones are shown in many excellent sections cut by the various streams, but they can be best studied at Gatelawbridge and Closeburn quarries. The Gatelawbridge quarries

Digitized by Google

(Mr. Marcus Bain) have been open for about two hundred years, and they are remarkable for having been the scene of some of the labours of "Old Mortality." Near the quarry is an Ionic cross of the red sandstone, which is many centuries old, but still shows the original ornamentation as distinct as ever. The greatest depth worked is about 100 feet, and the quality does not vary regularly with depth. It is almost all suitable for grindstones. The beds are not so steep on the average as at Mauchline, and it is easier to quarry. Much of the stone is worked by machinery, and sent from the quarry planed, moulded, and ready for setting on the job. They use steam rock drills, and a heavy steam Ingersoll machine for taking down the walls of the quarry. The effect of machine working will be further discussed under "Weathering." A feature of this rock, more or less common to all red sandstones, consists in the presence of occasional small black round spots, varying in size up to $\frac{1}{4}$ inch diameter, which, on being tested, seems to be due to the segregation of carbonaceous material. Sometimes they appear after erection, but usually grow less apparent through time. The dark portion appears to be about $\frac{1}{2}$ inch deep, and is slightly softer than the rest of the stone. Though the spots become invisible after weathering a little, they show up again when the stone is polished or cleaned. Gatelawbridge is on the average somewhat lighter in colour and finer in grain than Locharbriggs. Much of it is sent to Glasgow, though Edinburgh claims a large share, while shiploads are sent to Canada and the United States. The following buildings have been erected prior to September, 1905:—

Allan Line Offices, Glasgow.
Sir John Neilson Cuthbertson School, Glasgow (1905).
Municipal Buildings, Coatbridge.
Southwick Church, near Dalbeattie.
Post Office, Paisley.
Episcopalian Church, Kirriemuir.
Wilson Memorial Church, Perth.
Presbyterian Church, Selkirk.
Roman Catholic Cathedral, Cardiff.
Scottish Temperance Insurance Buildings, Belfast.

The quarries of the Scottish Freestone Company, Limited, at Closeburn (C. Halsall, manager), are separated by several hundred yards. The working face is 90 to 100 feet deep, and might be carried much deeper, as the rock is good, but for the presence of water. The quality of rock is in many

Digitized by Google

parts of the quarries suitable for grindstones of 4 to 5 feet diameter. False bedding is again a most noticeable characteristic. The colour is uniform, but a deeper red than most of the New Red Sandstones. The dark spots are not common here. A few are found in the softer beds. The hardness, working, and grain are very much like Locharbriggs. It shows no sign of decay at the seaside a number of years after erection. The Closeburn red freestone has been used in the following:—

King's Theatre, Tollcross, Edinburgh (1904).
Municipal Art Schools, Edinburgh.
Bangour Asylum, Edinburgh (1902).
Fever Hospital Edinburgh (1901).
Free Library, Montrose.
Blackness Library, Dundee (1907).
St. Mark's Church, Perth (1906).
R.C. Church, Stirling.
Savings Bank, Dundee.
Theatre, Kirkcaldy.
King's Theatre, Gateshead.
Congregational Church, Whitley Bay.
Union Bank, York.
Church and Institute, Muirkirk.
St. Enoch Station (Widening), Glasgow.
Clyde Bridge Offices, Glasgow.
New Technical College, Glasgow.[1]
N.B. Railway Buildings, Bridgeton, Glasgow.
Woodlands Mansions, Charing Cross, Glasgow.
Daily Mail Offices, Glasgow.
Central Agency Buildings, Glasgow.
King's Theatre, Glasgow.
Buchanan Street Properties, Glasgow.
Parish Church, Govan.
Theatre, Greenock.
British Linen Bank, Airdrie.

[1] Partly of Cove near the ground.

4. *Dumfries Basin.*—The Dumfries area begins as far north as Ellisland, and extends southwards beyond Maxwelltown and Dumfries, to a few miles past Caerlaverock, by way of Lochar Moss. The river Nith flows a little to the east of the centre of the basin for a large part of its course. The red rocks here rest directly on the Silurian strata without the Carboniferous beds, or even the volcanic zone of the Permian. It is clear that a long period has elapsed between the formation of the underlying Silurians and the New Red Sandstones, as seen, for example, in the Cargen Water, near the Glen Mill. The western portion of the area contains a great deal of breccia. An excellent section has been exposed within recent years in the cutting at the Dumfries sewage beds, especially on the north side, where the junction of the sandstones and breccia is well seen, the latter overlapping at an angle of about 45°. There are exposures on three sides. The northern one is about 60 feet long by 16 feet deep. The breccia con-

Digitized by Google

sists of a rare and varied assortment of angular and sub-angular, but never rounded, fragments of Silurian grey-wackes, shales, granite, limestone, dolerite, pink felstone, schists, and vein quartz embedded in a gritty paste. At Castledykes and Maidenbower Craig there is also considerable brecciated material, and the sandstone contains numerous boulders and pebbles of igneous rock. The Maiden-bower outcrop is adjacent to an old quarry, and forms a striking feature in the landscape. The breccia is in many cases interbedded with the sandstone, and the angular frag-ments are huddled together in a sandy matrix. There is also a good section on the railway to Dalbeattie, near Goldielea. Throughout all the sections a most conspicuous feature is the angular form and perfectly unweathered aspect of the rock-fragments, which are often of large size. On the flanks of the granitic areas near Dumfries the breccia con-sists of fragments of granite. The evidence points conclusively to a subaerial origin of the breccias and the local origin of their constituents.

The various quarries in the basin are Locharbriggs, Maiden-bower, Georgetown, Castledykes, Quarrelwood, Bankend, and Greenmill, the first named only being worked regularly. The quarries at Locharbriggs, of which most of the town of Dumfries is built, are owned by Messrs. Lowther, Halliday & Forrest, and by Messrs. Baird & Stevenson. The greatest depth worked is about 100 feet below rock surface, and, owing to water, the present workings are mostly not over 80 feet, as in so many other good quarries. Good rock is found almost beneath the soil, so that the amount of " tirr " is small. The bedding shows great variations. In some places the rock is so steep, 45° or over, that it has to be worked on ladders, while in others adjacent to this it may be almost horizontal. The quality is always excellent where the beds are steep. This is probably due to the fact that there would be more circulation and greater tendency for mud and inferior binding material to be carried further away, and deposited where the current action was less. Locharbriggs is fairly deep red in colour, rather coarse grained, of medium hardness, and easy working. Most of the stone

Digitized by Google

goes to Glasgow. The following buildings are of Locharbriggs stone:—

Art Galleries (outside), Glasgow.[1]
Central Agency Buildings, Glasgow.
Liberal Club (building), Glasgow.
Gartloch Asylum (outside), Glasgow.
Dykebar Asylum, Glasgow.
Govan Town Hall.
Paisley Infirmary.
Paisley Grammar School.
Moore, Taggart & Co.'s Warehouse, Trongate, Glasgow.
Govan Municipal Buildings (1898).
Herald Offices, Glasgow.
Walker's Trust Building, Sauchiehall Street, Glasgow.
Mercantile Chambers, 53 Bothwell Street, Glasgow (1902).
British Linen Bank, Glasgow, High Street Branch (1896).
British Linen Bank, Glasgow, Main Street, Gorbals, Branch (1901).
British Linen Bank, Glasgow, Govan Branch (1900).
Savings Bank, Glasgow, Anderston Cross Branch (1902).
Temperance League Offices, Glasgow, (1895).
Office Buildings, 144 St. Vincent Street, Glasgow (1902).
4 Tenements, 283-301 Main Street, Shettleston (1905).
5 Tenements, 28-52 East Main Street, Shettleston (1909).
Stonework of Queen Alexandra Bridge over Wear, Sunderland (1908).

[1] The Art Galleries are partly built of Cove red sandstone.

At Georgetown the material was similar, except that the bedding was thin and the stone flaggy. It was a good weather stone, and the colour much like Locharbriggs. Castledykes is a very deep red stone, somewhat softer and easier to work, open grained, but less weather resisting, and not so strong. This quarry was at the south end of Dumfries, close to the river. The back of Greyfriars' Church, now very much decayed, was built of it. It was also used for Sweetheart Abbey and the Mid Steeple, Dumfries. It does not stand very prolonged weathering, as seen in these examples, though the Mid Steeple is about two hundred and fifty years old. Maidenbower, some of which was used for the Crichton Royal Institution, Dumfries, is also a soft, deep red, easily worked rock of indifferent weathering power, but, owing to "dries" in the stones, no large blocks could be obtained. Quarrelwood is on the road to Auldgirth, about 6 miles from Dumfries. No large blocks could be obtained, owing to shallow bedding. The stone was of the usual red colour, of fair weathering capacity, and similar to Locharbriggs in grain. It was worked for a short period about five years ago. The old bridge at Auldgirth was built from it about a hundred years ago. Throughout all the same false bedding, and more or less deep red colour, is evident and characteristic. The notes given are for average material in each. A quarry is at present being worked at

Digitized by Google

Bankend, in the parish of Caerlaverock, about 6 miles south of Dumfries. At Greenmill, about half a mile north of this, footsteps similar to those of Corncockle are recorded as having occurred on the fine faces of the flags (*Jour. of the Geol. Soc.*, vol. vi., paper by Robert Harkness). Footsteps are also recorded for the lower flaggy beds at Maidenbower, and for one of the lower beds at Locharbriggs, but no description is given. There is still a very large quantity of good rock in the Dumfries basin. The Nith in its course for several miles above Dumfries has exposed excellent sections of first-class, workable building material.

5. *Annan Basin.*—The Annan area is only separated from the Dumfries one by a few miles. The break is between Cummertrees and Annan, where the Permian rocks are wanting, having been denuded away, and the Calciferous Sandstone series comes to the top. The Permian beds in Cumberland are really a continuation of those in the Annan area. The basin extends from Annan by way of Kirtlebridge, Springkell to Canonbie, and encloses about 64 square miles. Quarries have been worked at Annanheath, 1 mile north of Annan, at Corsehill, 2½ miles north of Annan, at Kirtlebridge, 6 miles N.E. of Annan, and at Cove, on the Caledonian Railway from Lockerbie to Carlisle, close to the Kirtle Water, and about 7 miles from Annan. The workings of Messrs. J. Murray & Sons at Corsehill are very extensive. The red sandstone is here associated with a considerable amount of red shales and clays. The amount of "tirr" is greater than usual, being in many places over 20 feet, but the quality of the underlying rock is not thereby affected. The stone is, on the average, very fine and even grained, and takes a very fine polish. Some of it is rather clayey. The greatest working depth is about 100 feet below the surface, and the stone becomes slightly harder at the bottom. The small black spots are found in the very bottom of the quarry. The beds are fairly level. The rock is not at all steeply bedded, and there is little or no false bedding, certainly much less than in the new red quarries of other areas. It occurs in various shades, from blood-red to bright or pale pink, which may be used by way of contrast. It is slightly lighter in

Digitized by Google

colour than Locharbriggs, on the average, and finer in grain. This stone is excellent for all inside work and for ornamental work and carving, as on monuments, panels, mausoleums, quoins, sarcophagi, and plinths for marble monuments. It carries a sharp arris, and is very free and clean in working. When weathering it tends to form ridges, showing dark red veins. Some of the buildings in which Corsehill stone has been used are given in the following list:—

Villas at Dumbreck, Glasgow (1896-1908).
Columns, Balusters, &c., University, Edinburgh.
Columns, Balusters, &c., Princes Street Station, Edinburgh (1894).
New British Linen Company's Bank, Renfrew (1898).
National Picture Gallery, Edinburgh.[4]
North British Distilleries, Edinburgh.[4]
Sick Children's Hospital, Edinburgh (1892).
Marquis of Bute's Mansion, Mount-Stuart.[4]
St. Paul's Station, Queen Victoria Street, London.[3]
Weights and Measures Offices, Clerkenwell.[3]
Jews' Synagogue, Great Portland Street, London.[3]
Free Middle Church, Perth.[4]
New Post-Office, Fort-William (1896).
Station House and Buildings, Fort-William (1894).
Lighthouse on one of Flannan Isles, west of Island of Lewis (1899).
Lighthouse, Portpatrick, Wigtown (1900).
New Bank Buildings, Royal Avenue, Belfast (about 1898).
New Church, Cork (about 1898).
National Bank, Rathmines, Dublin (about 1898).
Petroleum Exchange, New York.[2]
Casino Theatre, New York.[2]
Western National Bank, Baltimore.[2]
Princeton College, N.J.[2]
Fever Hospital, Stockwell, S.W.
St. James's Hall, Piccadilly, London.[3]
New Premises, "Folkets Slus," Stockholm, Sweden.[1]
New Premises, 3 and 5 Birker Jarls Street, Stockholm, Sweden.[1]

[1] 8 to 10 years ago.
[2] 15 to 20 years ago.
[3] About 20 years ago.
[4] Over 20 years ago.

Cove quarry is practically similar in all respects to Corsehill, but the rock is perhaps slightly softer. It has been closed for over twelve months. In the paper already quoted, Harkness says that marks of *Cheirotherium* sometimes occur in relief on the upper surfaces of the Annan strata, and are like those of the Cheshire sandstones. Lines of dessication were also common.

6. *Lochmaben and Corncockle Muir.*—This basin includes an area of about 34 square miles. Lochmaben is situated a little to the south of the centre, and the longitudinal axis runs parallel to the Dumfries basin. Annandale, like Nithsdale, consists of hollows in the Silurian hills. The well-known quarries of Corncockle Muir are situated a few miles from Lochmaben, and are owned by Messrs. Benson & Co. They

Digitized by Google

are famous for the discovery of Permian labyrinthodont footprints about sixty years ago. These consisted of impressions of the feet of tortoise-like animals walking on the soft sand, such as would occur in connection with shallow bodies of water and areas of inland drainage. The shallow shores would present a large surface of mud and silt on a slight lowering of the water level. Across these air-breathing vertebrates would wander. The imprint thus formed would be covered over with a layer of dry sand, probably wind blown, then with wet sand or mud, and the whole has ultimately been consolidated and hardened into sandstone. These records are remarkable as being the best evidences presented by the New Red Sandstones of the life of the period. Specimens are exhibited in Maxwelltown Observatory. They were drawn and described by Sir William Jardine in 1853 in "The Ichnology of Annandale." The most common impression on the Annandale sandstones was *Chelichnus duncani*, Owen. At one time a track 30 feet long was laid bare, which went first in a straight line, then in different directions. The paces were uniform, and the size of footprint from 1·5 inches in length to 1·2 inches or 1·3 inches in breadth, with irregular oval outline in front. The length of stride was about 1·5 inches or 1·6 inches. It was supposed from this that the average size of tortoises is from 7 inches to 8 or 9 inches long by 5½ or 6 inches broad. A long and lithe-like animal—probably a Saurian aspect—was described as *Herpetichnus sauroplesius*, Jard. The other specimens were *Chelichnus gigas* (length of stride, 16½ inches), *Chelichnus titan*, *Chelichnus ambiguus*, *Chelichnus plagiostopus*, *Herpetichnus bucklandi*, and *Actibates triassœ* (all Jard.). A slab from Greenmill quarries, in the Nith valley, contained the marks of the foot of a Batrachian, *Batrachnis lyellii*, Hark., with regular pace, deliberate and alternate.

The greatest depth to which the rock has been worked is about 110 feet, at which depth the quality remains good. The bedding is fairly steep, perhaps about 1 in 3 on an average. The north end gave good grindstones, but is not at present being worked. The colour is somewhat brighter, and the grain rather finer than Locharbriggs or Gatelawbridge, and

Digitized by Google

it is softer on an average, though some of it is harder to work. Examples of its use in construction are—

Balshagray School, Partick.
Victoria School, Govanhill.
Ibrox Schools.
Govan High School (1909).
Kinning Park School (1909).
Parish Council Offices, Glasgow (1901).
U.F. Church, Clydebank (1906).
U.F. Church, Cathcart.
Administrative Block of Argyll Motor Works, Alexandria.

7. *Moffat.*—This is a northern extension of the Lochmaben area, and is 12 miles long by 1 mile average width. The town of Moffat lies a little to the north of the centre of the area. No quarries or working of any account seem to have been opened in this district.

8. *Ballantrae.*—Two narrow parallel strips about 2 miles long are shown on the Survey map for the Ballantrae district. The outer one is just being exposed by the sea at Ballantrae Bay. They consist of thin bedded fissile red sandstones, frequently ripple marked, and cut by dykes. They are associated with red breccias. No economic development has taken place.

III. White Decolorised Rock.

Portions of white rock occur in many of the New Red Sandstone quarries. It is found in two distinct habits. At Ballochmyle and Barskimming, in the Mauchline area, it is very approximately spherical, and varies in size from a fraction of an inch to as much as 12 inches diameter. The line of demarcation between the white and the red is always distinct, but there is no change in the texture. It is in the colour alone. This phenomenon invariably is found in rock of the best quality, though large blocks of poor rock are sometimes found covered with small white spots up to about ½ inch in diameter. There may be some hundreds of these on the face of a stone 8 or 10 square feet area. The very large white spots, so far as the writer knows, have only been found at Mauchline, Corsehill, and Locharbriggs; and always in good rock. At Arran they may be up to 2 inches diameter. White spots are also frequently found in other sandstones, as for example, the Carboniferous, on the railway at Tarbolton station, and in others at Port-Glasgow, Largs, and Dumbarton. The results of analyses made by Mr. J. W. Young on specimens

Digitized by Google

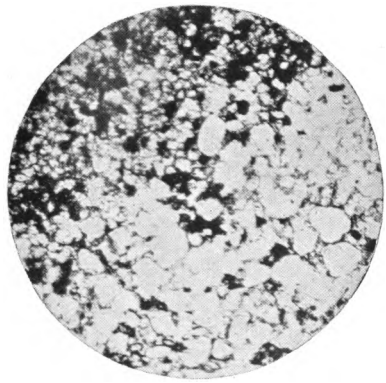


Fig. 1.—Section of Ballochmyle Red Sandstone, × 16.
The upper portion is red and the lower white.

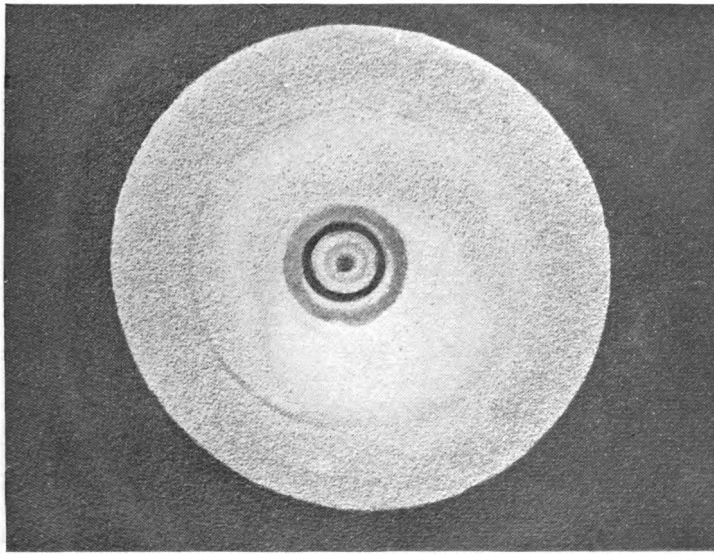


Fig. 2.—Polished Slab of Ballochmyle Red Sandstone, with white decolorised sphere about 10 inches diameter, containing white and green alternate inner rings.

Digitized by Google

Digitized by Google

from the three latter localities show ("Chemistry of Sandstones," *Trans. Geol. Soc. of Glas.*, vol. ii., pt. 1) that the white portions contain from 70 to 80 per cent. less peroxide of iron than the red portions. The peroxide or red oxide can be removed by the action of hydrochloric acid. These red sandstones have, first of all, been coloured by solutions of ferrous carbonates and sulphates depositing the insoluble peroxide. The red colour is due to the peroxide, which arranges itself as a thin coating round each little grain of quartz. It may, however, be present as small specks disseminated in the mass, in which case it exerts little or no colouring effect. If the extra molecule of oxygen in the red oxide be acted on by the carbon of decaying vegetation it will be abstracted, leaving the protoxide of iron, which may exist in large quantities without colouring the sandstone at all. The bleaching or decolorisation appears therefore to be due to the reduction of peroxide of iron to protoxide. The oxygen liberated would now help to form CO_2, which in combination with percolated water as H_2CO_3 would dissolve the iron, and remove it as carbonate. The definite margin between the red and the white may be explained by the fact that the reduction would cease all at once, so that there could be no gradual merging of the red colour into the white. Fig. 1, Plate XXII., shows a microscopic section at the junction of the white and red portions in a specimen of Ballochmyle sandstone. The white in this case was almost truly spherical, and about 2 inches diameter. It appeared to be more loosely cemented than the red, and consequently the section was difficult to make thin enough. The grain of both was open and coarse (average diameter of 0·01 inch). It will be seen that there is no definite line of demarcation between the white and red, but the one is completely interlocked with the other, forming a homogeneous mass. The change is in the colour alone, as seen from the cementing material surrounding the sand grains. The white part is not due to infiltration. The red portion contains an exceptionally large number of crystals of iron ore. The few in the white appear more decomposed. Some of the iron is in rounded grains, other crystals are irregular, and appear to be derived from decomposing minerals, like felspar and biotite. Crystals of white mica very similar to the

Digitized by Google

quartz are sprinkled among it, and there are a few decomposing felspars.

The chief difficulty is to account for the decaying vegetation or vegetable matter, which gave rise to the carbon. Some specimens show two spheres of white merging into each other as if there had been two centres of reduction. A probable explanation, and the usual one given, is that it was some decaying organism, plant, or animal which gave rise to it, and thus produced the decolorised portion. The organism would be of nearly spherical outline. This, however, does not sufficiently explain all cases. Fig. 2, Plate XXII., shows one of the white spots from Ballochmyle quarries, which is in the possession of Mrs. Macqueen, Mauchline, who gave permission to have it photographed. It is about 10 inches diameter, and contains a number of dark greenish inner rings. This is the only specimen on which such a feature has been observed. The green bands appear to be due to the replacement of ferric oxide by the pale green ferrous silicate. There is a remarkable specimen in Kelvingrove Museum from the bed of the river Nith with an agate-like structure. It contains several centres of variegation. The outer circles are not over $1\frac{1}{4}$ inches diameter. The centre spot is sometimes brown, sometimes white, and these colours are arranged alternately in rings from the centre outwards. The general conclusion of the author is that the presence of variegated and poikilitic mottling in sandstones and of all decolorisation as described is due primarily to particles of organic matter; and that a species of *chemical segregation* has in many cases taken place from a centre or several centres by which alternate reductions could take place. It would be an interesting research to attempt an experimental demonstration of the fact.

White rock occurs in a second form, that of irregular masses of a few hundredweights up to many tons in weight. The line of demarcation as regards the colour is again more or less abrupt, but there is no break in the texture. In the Thornhill area at Gatelawbridge irregular masses of white rock are occasionally found. One large strip has occurred, running across the strata, varying from 3 inches to 15 inches thick, and about 40 to 50 yards long. Other portions met with are quite local and irregular, and the volume only a few cubic feet.

Digitized by Google

In one case a white part was surrounded by a narrow belt of still whiter rock. White rock is met with at Locharbriggs, in the Dumfries area, in isolated, irregular patches and masses, and at Barskimming, in the Mauchline area. White in mass is also largely found at Corsehill, in the Annan basin, and there the white is of particularly good quality—fine, even grained, and compact. The masses are large and irregular. These are not found at Ballochmyle or in the Lochmaben area. No defined beds of white are met with at Closeburn. In support of the theory of decolorisation by organic matter, it may be pointed out that sand is often whiter when in contact with decaying roots and branches of trees or shrubs. This may be seen, for example, along the Ayrshire coast. The irregular white masses appear to be due to organic matter in particles obtaining temporary access to the lake, and preventing the formation of the red oxide. Occasional portions would account for local irregular patches of white.

Numerous basic dykes in various directions cross the foreshore of the east coast of Arran between Corrie and Brodick Castle. They remove the red colour of the rock, making it white or yellow, and harden it. This is again a chemical change.

IV. Chemical Composition and Petrology.

The chemical analyses have been kindly supplied by the various quarry owners, and the name of the chemist is given in each case. The nature of the cementing material has been arrived at from the microscopic section, the analysis, and by submitting small chips of the rock to heat in a test tube with hydrochloric acid, when the residue could be examined, after its separation from the quartz, mica, and other constituents. The specific gravities were found from carefully dressed and measured cubes of the material, which were weighed on a balance correct to at least 0·5 gramme, or about 0·1 per cent. of the weight of the cube. The linear measurements could be relied on to 0·7 per cent. This method had to be adopted owing to the high absorption. The order of description is—(*a*) Macroscopic examination, (*b*) chemical analysis, (*c*) microscopic examination.

Digitized by Google

The order of description is—(*a*) Macroscopic examination, (*b*) chemical analysis, (*c*) microscopic examination.

1. *Arran—Corrie.*

(*a*) Deep or dull red, fairly coarse, even-grained rock.

(*c*) It consists of numerous well-set, rather coarse grains of quartz, averaging 0·01 inch diameter—with a few flakes of muscovite—uniform in size, rather well rounded, but sufficiently interlocked and bound together with a definite brownish cementing material, mainly ferruginous, as a thin coating round the sand grains and in the subangular spaces between. Half-decomposed felspars are often locked between the quartz grains. There is a little iron ore, probably hematite, apparently mostly formed from decomposing felspar or decomposed biotite.

2. *Mauchline—Ballochmyle.*

(*a*) Open-grained, porous rock of medium density. Colour, orange-red to red. Specific gravity, 2·07 to 2·03.

(*b*) (Dr. Wallace, Bath Street, Glasgow.)

27th Nov., 1885.

	Ballochmyle.	Barskimming.
Silica,	96·36	97·44
Alumina,	1·13	0·64
Oxide of Iron,	0·65	0·64
Carbonate of Lime,	0·19	0·14
Carbonate of Magnesia,	0·42	0·21
Magnesia in other combinations,	...	0·24
Combined water loss,	1·00	0·42
Water at 212° F.,	0·48	0·38
	100·23	100·11

(*c*) The average section consists of small, fairly angular grains of quartz ·012 to ·006 in diameter, usually well interlocked and occasionally in two sizes, the smaller grains filling

Digitized by Google

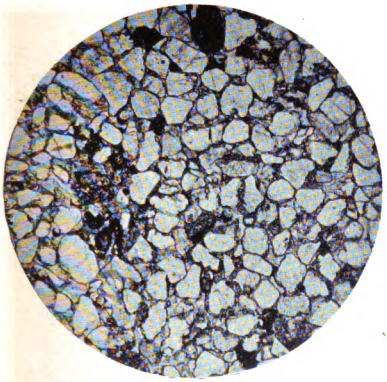


Fig. 1.—Arran Sandstone, × 16

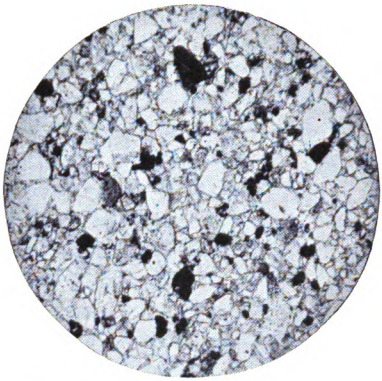


Fig. 2.—Mauchline Sandstone, × 16.

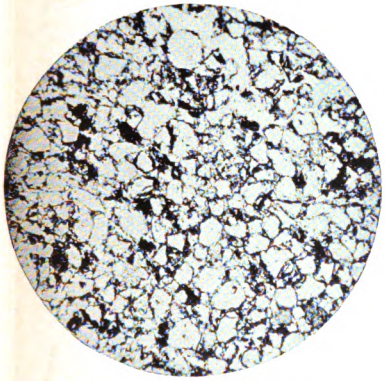


Fig. 3.—Gatelawbridge Sandstone, × 16.

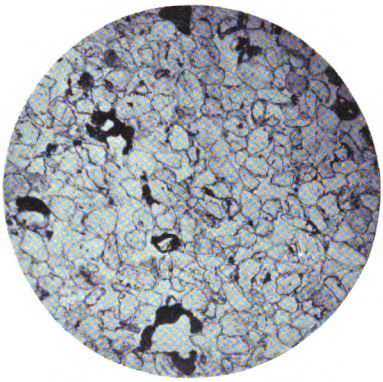
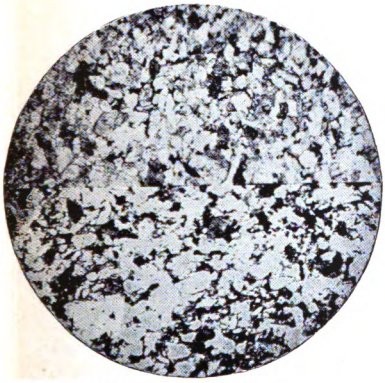


Fig. 4.—Locharbriggs Sandstone, × 16.



White. Red.
Fig. 5.—Corsehill Sandstone, × 16.

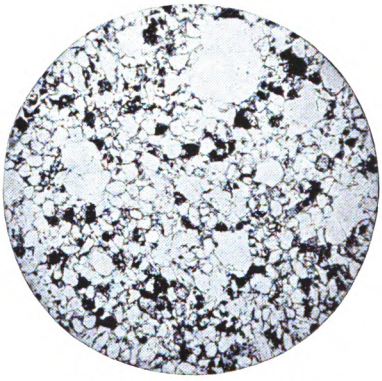


Fig. 6.—Corncockle Sandstone, × 16.

New Red Sandstones of the South and West of Scotland.

Digitized by Google

Digitized by Google

up the interspaces between the larger. The cementing material is thin and definite, and is composed of iron oxide and alumina with a small proportion of carbonates. Many quartz grains show small inclusions. The felspars are few in number, of turbid appearance, and show decomposition into china clay, and to iron oxide along cracks. Both cleavages and Carlsbad twinning are sometimes seen. A few flakes of muscovite occur scattered irregularly through the mass. There is subsidiary iron ore, much of which is in the form of original grains. A crystal of calcite with two typical oblique cleavages has been identified. Sections near the base of the sandstone series show more numerous spots of hematite or magnetite, with sand grains less regular in size, and sometimes of more rounded grains, in groups separated by doubtful, cloudy, cementing material. There are small, dark particles, probably carbonaceous matter.

3. *Thornhill*—(*A*) *Gatelawbridge.*

(*a*) Red or orange-red rock of medium coarseness. Specific gravity, 2·38 to 2·08.

(*b*) (Dr. Clark, Glasgow.)

Siliceous matter,	97·70	per cent.
Alumina,	0·75	,,
Oxide of Iron,	0·55	,,
Lime,	0·10	,,
Magnesia,	0·10	,,
Sulphate of Lime,	none	,,
Combined water, &c.,	0·26	,,
Moisture,	0·41	,,
	99·87	,,

(*c*) Quartz occurs as angular and subangular grains, ·01 inch mean diameter, with occasional inclusions, in one case tourmaline. Felspar is much decomposed, but small in quantity. There are occasional yellow flakes of muscovite, sometimes showing cleavages. Iron ore is present as original,

Digitized by Google

well-rounded grains. Other crystals are stringy in form, and evidently derived from decomposing felspars. The change may be seen taking place along both cleavage planes and the periphery so as to surround the crystal entirely. The sand grains are held together with a light brownish-yellow cement, which is mostly iron oxide, and they are well interlocked. The small, rounded particles, probably carbonaceous, and more or less common to all, occur here.

(*B*) *Closeburn.*

(*a*) Deep red rock of medium grain and high density. Specific gravity, 2·61 to 2·14.

(*b*) (A. V. Elsden, F.C.S.)

Silica,	91·06 per cent.
Alumina,	4·50 „
Ferrous Oxide,	0·07 „
Ferric „	0·97 „
Calcium „	0·30 „
Magnesium Oxide,	0·33 „
Potassium „	2·50 „
Sodium „	trace „
Loss on ignition,	0·83 „
	100·56 „

(*c*) The section mostly consists of fairly angular quartz grains of uniform size with a little muscovite and some cloudy felspars. The cementing material is iron oxides and argillaceous substance. The latter, however, seems to form a chemically stable matrix.

4. *Dumfries—Locharbriggs.*

(*a*) Rather coarse grained, fairly deep red rock of medium hardness and density. Specific gravity, 2·46.

Digitized by Google

(*b*) (R. R. Tatlock, F.I.C., F.C.S.) 9th May, 1889.		(Jas. Davidson, F.I.C.) 16th Nov., 1900.	
Siliceous matter,	97·88	Silica,	98·29
Alumina,	0·38	Oxide of Iron, &c.,	1·18
Oxide of Iron,	0·80	Moisture,	0·53
Carbonate of Lime,	0·25		
Carbonate of Magnesia,	0·10		100·00
Phosphate of Lime,	trace		
Sulphate of Lime,	trace		
Loss on ignition,	0·50		
Water,	0·09		
	100·00		

(*c*) This consists of a closely fitting mosaic of quartz fragments of fairly uniform size, ·009 inch diameter, well interlocked, and probably derived from the denudation of Silurian igneous rocks and granites near Dumfries. Some of the grains contain inclusions. There is a very little cloudy felspar occasionally with single and multiple twinning, undergoing decomposition into iron ore on the periphery. Muscovite is irregularly distributed in thin, rounded flakes, with low polarisation colours. The mineral kyanite has been identified in this rock as round, bluish crystals. There are a few doubtful crystals, probably biotite, and occasionally apatite.

5. *Annan—Corsehill.*

(*A*) (*a*) Red. Fairly dense, very fine, even-grained, compact, light red, micaceous rock. Specific gravity, 2·26 to 2·1.

(*b*) (Dr. Wallace, F.R.S.E., F.C.S.)

2nd April, 1880.

Silica,	95·24	Water absorbed by dried stone, when immersed, 6·25 per cent.
Alumina,	0·56	
Peroxide of Iron,	1·28	
Carbonate of Lime,	1·40	
Carbonate of Magnesia,	1·23	
Moisture,	0·56	When exposed to air, moisture dies down to ½ per cent.
	100·27	

(*c*) There are numerous small angular and subangular quartz grains, ·005 inch diameter, not well rounded, fairly well inter-

Digitized by Google

locked, but separated by many patches of greyish decomposed felspars. Most sections show a few yellow crystals of white mica, and some have a good deal of iron ore. The latter is seldom rounded, but mostly irregular, and often as a thin strip round the edges of a decomposing mineral. The cementing material is largely argillaceous, but probably sometimes contains iron oxide and carbonates in small quantity. It is yellow-brown in sections, sometimes very definite, but in rather large quantity.

(*B*) (*a*) From white rock in mass. Very compact, even-grained, clean white rock.

(*c*) The quartz grains are small and in clusters, separated by large kaolinised felspars. Many grains are round and elongated, others subangular. None are well rounded. There is much greyish decomposed felspar, almost isotropic, breaking up the homogeneity of the sand. A few crystals are rectangular in form. Hematite is present in ragged outlines as a peripheral decomposition product. The cementing material is rather indefinite, and seems to consist largely of clayey material.

6. *Corncockle.*

(*a*) Fine-grained, fairly soft, bright red rock of even texture. Specific gravity, 2·12.

(*b*) (Mr. W. H. Blake, Newcastle.)

Silica,	94·75 per cent.
Alumina,	2·81 ,,
Iron Oxide,	0·09 ,,
Lime,	0·20 ,,
Magnesia,	0·27 ,,
Alkali Metals,	0·08 ,,
Water,	1·77 ,,
	99·97 ,,

(*c*) The quartz grains are in two sizes, one fairly large (·025 inch diam.) and scattered, the other small, and more compactly arranged. The mean diameter is ·006 inch. All are more or less elongated, but rounded, and compactly interlocked. Muscovite is present in a few irregular or rounded flakes of yellow colour. There is a little felspar recognisable. Hematite or

Digitized by Google

magnetite are uniformly scattered throughout the mass, mostly ragged and developed round decomposing minerals. The cementing material is a mixture of alumina with lime and magnesia, perhaps mainly due to decomposed felspar. There is a small amount of coloured decomposition products, chloritic or serpentinous.

V. The Testing of Sandstone.

Crushing.—When sandstone or any similar rock or brittle material is tested in compression it fails by shearing on a certain definite plane, making an angle of about 60° with the horizontal. The universal custom has been to test cubical specimens. It is now definitely established that the unit strength is independent of the size of the cube, or the size of a cubical specimen is immaterial as regards the ultimate crushing strength per unit of bed area. This was shown by Gillmore in experiments at Watertown (Mass.) Arsenal. To consider the effect of crushing let a prism *a c e d* of the material be subjected to a direct compressive force *P*, as in Fig. 1. On

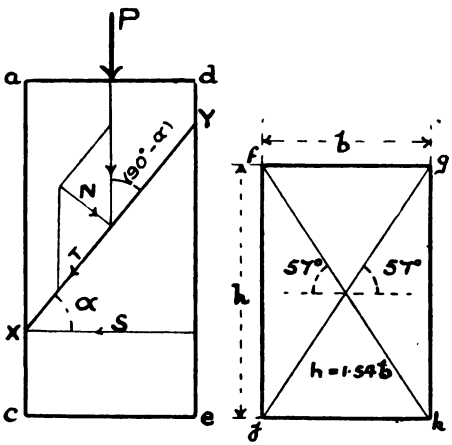


Fig. 1. Fig. 2. Fig. 3.

any plane section, such as *X Y*, there will be a normal compressive component *N*, and a tangential component *T*, of the pressure *P*. The latter will tend to produce a shearing stress on the plane *X Y*. Coulomb showed that if we consider only this force, and neglect the friction due to the normal force *N*, the shearing stress attains its maximum value on

Digitized by Google

planes inclined at 45° to the axis. Rankine and many other writers have followed Coulomb, but it seems obvious that the normal component will produce an appreciable resistance to the rubbing of the two surfaces.

Let p = unit crushing strength of the sandstone.
s = unit shearing strength of sandstone.
α = angle which plane of rupture makes with horizontal.
β = angle of repose of sandstone.

The tendency to slide on $X\ Y$ must be balanced by the resistance due to the shearing component along $X\ Y$ plus that due to friction. Therefore at rupture

$$p \sin. \alpha = s \sec. \alpha + p \cos. \alpha \tan \beta. \quad - \quad - \quad - \quad (1).$$

Putting $\cos. \alpha = \frac{1}{u}$ and using the relation $\frac{dp}{du} \times \frac{dp}{d\alpha} = \frac{dp}{d\alpha}$

We have

$$\frac{dp}{d\alpha} = \frac{s \sin. \alpha}{\cos.^3 \alpha} \quad \frac{(\sin.^2 \alpha - \cos.^2 \alpha - 2 \sin. \alpha \cos. \alpha \tan \beta.)}{(\tan \alpha - \tan \beta.)}$$

= 0 if the angle of rupture is to be that for a minimum load. Hence

$$\tan \beta = - \frac{\cos.^2 \alpha - \sin.^2 \alpha}{2 \sin. \alpha \cos. \alpha} = \tan (2\alpha - 90) \quad - \quad - \quad (2).$$

$$\alpha = \frac{\beta}{2} + 45°$$

or the angle of fracture is 45° plus one-half the angle of repose. The latter value for specimens of the New Red Sandstones has been found experimentally by the writer to be on the average 24°. Hence the angle of rupture is 57°. The fundamental point to be noted here is, that, if a cube be tested, the material is not free to fail along the true plane of rupture, and consequently the apparent unit strength is greater than the real unit strength of the material. It has, unfortunately, been the custom almost universally to test cubes. If the maximum shear occurred on planes at 45° the cube would tend to break up into six pyramids, with their apices at the centre. Bauschinger found that when the specimen was of sufficient height the angle of rupture for sandstone was about 55° to the horizontal, and Charles Bouton (M.S. Degree Thesis, Washington University, 1891) found that the theoretical angle for materials, such as limestone, asphalt, brick, and cast-iron, was well borne out in actual experiment, the maximum variation being 3 per cent. for cast-iron. As already indicated, the angle of rupture

Digitized by Google

for the red sandstones is about 57°, so that (Fig. 2) to allow this to take place the height of the specimen h must be at least equal to 1·54 b, the least breadth, or approximately $h = 1\frac{1}{2}\ b$. Cubical specimens tend to rupture in many cases into conical pieces $m\ v\ n$ and $o\ v\ q$ (Fig. 3). Professor Hudson Beare (M.P.Inst.C.E., vol. cvii.) found that the two sides corresponding to the top and bottom, or those in contact with the dies, remained intact, but the others, as $l\ z\ r$ in the same figure, usually crumbled into dust. The tests which have been made on cubes are, however, valuable from the point of view of the comparison of different building stones, but are of questionable value as to the idea of the strength of structures built of such stone, or of the crushing strength of stone in large masses. The strength, as determined from cubes, is usually from 8 to 10 per cent. greater than from specimens with $h = 1\frac{1}{2}\ b$. (See Appendix.)

The crushing strength is considerably influenced by the nature of the material between the specimen and the dies of the machine. Baker ("Treatise on Masonry Construction," 1900) states that under certain limits the following are the relative strengths obtained with different pressing surfaces:—Steel, 100; wood, 89; lead, 65; leather, 62. Hudson Beare investigated this point, and found that the loss of strength due to interposing $\frac{1}{8}$-inch lead sheets between the specimen and the dies varied from 37·8 to 52·6 per cent. from that with the specimen coated with plaster of Paris. This is due to the lateral flow of the lead under the great pressure. The crushing forces cause lateral dilatation, and a tension at right angles to the line of pressure. The lead flows laterally, and friction is set up between it and the face of the cube, which induces a tensile stress in addition to the one above. Professor Beare states that two specimens of Corncockle red sandstone with lead sheets interposed gave a mean strength of 195·1 tons per square foot, and one with pieces of pine gave 145·4 tons per square foot before breaking up, the value with a plaster of Paris coating being 383·8 tons per square foot. A thin coating of plaster of Paris on each face, which enables the surfaces to be made perfectly parallel, seems to be best, but the difference even then has been found by some experiments to be 10 per cent. from rubbed beds. Messrs. D. Kirkaldy & Sons,

Digitized by Google

London, whose experiments on red sandstone are quoted, state that their practice is now to grind the surfaces of the specimen perfectly true, and use no intermediate material between them and the dies.

Full tests for several of the new red rocks described are given in the Appendix, but for comparison the following are mean values on cubical specimens:—

Authority.	Name of Sandstone.	Size of Cube.	Number of Experiments.	Mean Stress in Tons per sq. ft.	
				Cracked slightly.	Crushed.
Kirkaldy & Son, -	Corsehill[1]	6 in.	3	635·9	635·9
Hudson Beare, - -	Corsehill[2]	2¼ in.	8	...	444·9
Stanfield, - - -	Closeburn[2]	2¼ in.	4	...	536
Hudson Beare, - -	Closeburn[2]	3 in.	8	...	478
Kirkaldy & Son, -	Gatelawbridge[1]	4 in.	3	428·7	439
Hudson Beare, - -	Gatelawbridge[2]	2¼ in.	3	...	495·7
Kirkaldy & Son, -	Locharbriggs[3]	6 in.	3	392·7	404·7
Hudson Beare, - -	Corncockle[2]	2¼ in.	3	...	383·8
Kirkaldy & Son, -	Ballochmyle[3]	6 in.	...	336·9	360·0

1. Bed surfaces ground true.
2. Specimen coated with thin layer of plaster of Paris.
3. Tested on beds between pieces of pine ⅜ in. thick.

As the result of crushing tests on 88 samples of 25 varieties of British sandstones, Hudson Beare obtained a mean of 489·8 tons per square foot, which will show how the red sandstones compare with the average. The values quoted above relating to tests between pieces of pine are probably too low by anything from 5 to 12 per cent.

Shearing Strength.—Very few experiments have been made in this direction, owing to the difficulty of testing, as bending stresses are introduced. Shear tests on Closeburn red sandstone by Professor Beare are given in the Appendix. The mean values are—For shear plane at right angles to plane of quarry bed, 158·8 tons per square foot; for plane of shear across the plane of bed, 180·3 tons per square foot. Using the same symbols as before, we have from equation (1) with tan β substituted from (2)

$p = 2 s \tan \alpha$ or $s = \frac{1}{2} p \cot. \alpha$. Using the value of s above for Closeburn stone tested at right angles to the bedding, and assuming $\alpha = 57°$.

$p = 2 \times 158{\cdot}8 \times 1{\cdot}54 = 489$ tons per sq. ft., which is within

Digitized by Google

2 per cent. of the value of p found by actual experiment, 478 tons per sq. ft., tabulated above.

VI. General Properties and Weathering.

The first part of a building to be attacked is generally that beneath a projecting ledge, a strong course or cornice, and at lintels and doorways. Many of the Glasgow buildings show clearly the solvent effect of acids below the windows sills and on the faces of the columns. The exposed parts of a building are cleaned by heavy showers, but the effect on the sheltered portions is to allow them to collect all injurious atmospheric matter. The sheltered surface also remains damp after the exposed ones are dry, due to water soaking through from higher levels. In the case of the Dumfries and Maxwelltown Ewart Public Library, built in 1902-03, of stone from Annanheath quarry, Annan, the decay was most marked under projections and on ornamentation. It was also worse on the front or sheltered side of the building which faces north and gets least sun. The exposed places were hardly affected. In one or two parts on the top of the building on a parapet there were clay holes large enough for the hand to be inserted. Decay became evident in 1905, and by 1906 the matter became so urgent as to call for action. The stone was analysed, and found to contain lime as well as alumina. The presence of alumina in itself would not be responsible for the decay. It is probable that the cementing material was of carbonate of lime and argillaceous matter, and that the former was removed by chemicals in the rain water. Though the carbonates of lime and magnesia are only slightly soluble in pure water, they are much more so in water charged with CO_2. The stone was very compact in appearance, and hard to cut. Microscopic examination at once shows the main cause of decay. The quartz grains are small and irregular in shape, arranged in groups with large decomposing felspars between. After the cement gave way the latter have been completely converted into china clay, the quartz grains have fallen asunder and been washed away, leaving only in parts a mass of argillaceous material. In 1907 it received a coat of "Czerelmy's Stone Fluid," which is the same as was used on the Houses of Parliament. It seems to have been effective on most of the building, but some carved figures with projecting base and the

Digitized by Google

stones under the base had to be done again in 1908. The solution has changed the colour of the stone from a rich red to a slatey greyish-red. It does not follow, however, that all rock taken from a particular quarry will weather alike. There are hardly any two strata which will yield exactly the same chemical results, and the rock of adjacent quarries may differ considerably. The percentage of carbonates, for example, in ordinary Giffnock sandstone has been given by different analyses of separate authorities as 2·17, 6·5, and 10·02. Though Corsehill stone is very similar to Annanheath, there are instances of it lasting very well even from seventy to one hundred years in the Dumfries atmosphere without appearance of decay.

Stones showing the largest amount of carbonates are "cæteris paribus," the first to show signs of decay. Those, like the Polmaise, which has decayed badly in Glasgow Municipal Buildings, contain a large percentage. The following table gives a summary of the chemical constituents of the New Red Sandstones, already given, with a few others for comparison:—

Name of Sandstone.	Percentage of				Specific Gravity (mean).	Absorbed Water per cent. (mean).
	Lime and Magnesia Compounds.	Silica.	Alumina.	Iron Oxides.		
Corsehill	2·63	95·24	0·56	1·28	2·18	6·76
Corsehill[1]	1·03	94·32	1·34	1·7	2·06	6·1
Closeburn	0·63	91·06	4·50	1·04	2·37	...
Ballochmyle	0·61	96·36	1·13	0·65	2·05	9·0
Corncockle	0·47	94·75	2·81	0·09	2·11	4·57
Barskimming	0·35	97·44	0·64	0·14	2·07	...
Locharbriggs	0·35	98·29	0·38	1·18	2·46	...
Gatelawbridge	0·20	97·70	0·75	0·55	2·23	7·67
Polmaise[1] (white)	12·58	84·14	0·52	1·92	2·19	4·4
Grange[3]	5·93	92·96	0·27	0·28	2·41	...
Pardovan[4]	5·30	83·3	9·54	1·68	...	...
Polmaise[1] (yellow)	4·51	93·2	0·32	1·20	2·20	5·0
Overwood[2]	4·07	87·5	2·5	2·84	2·32	...
Skares[2]	3·02	70·78	17·29	0·70	...	...
Giffnock[1]	2·17	94·94	0·56	1·22	2·11	5·9
Wemyss Bay[1]	1·11	96·67	0·81	1·05	2·08	7·2
Craigleith[1]	0·57	98·29	0·49	0·27	2·26	3·4

1. From *Trans. Roy. Phil. Soc. of Glas.*, vol. xiv. "On the Decay of Building Stones," by Dr. Wallace.
2. Analysis, by Dr. Wallace.
3. Analysis, by Dr. J. Clark.
4. Analysis, by George Craig.

Digitized by Google

The rocks have been arranged in the order of their percentages of lime and magnesia compounds. These are carbonates in all cases except Closeburn and Gatelawbridge, where they are oxides. The Grange and Skares stones contain 0·32 and 3·64 per cent. of carbonate of iron respectively.

Deductions.—It will be noticed that in general the lime and magnesia compounds are least in the best weather stones. The percentage in Locharbriggs and Gatelawbridge is very small. It is noteworthy that the latter stone is now used for the saucers under the condensing columns in the Ardeer factory—Nobels' Exposive Works Company, Stevenston. Prior to its adoption they considered it necessary to send to Austria for material suitable to resist the action of the strong acids. Its success in this respect is probably due, in a large measure, to the small proportion of lime and magnesia, and to the high percentage of silica, which is one of the characteristics of the New Red Sandstones. Stones like Skares, with only 70·78 per cent. of silica and 17·29 of alumina, can hardly be expected to stand an acid atmosphere. There seems to be no general law connecting the percentages for the New Red Sandstones given in the table. It might be expected that the specific gravity would be directly, and the porosity, inversely, proportional to the quantity of lime and magnesia carbonates, but this does not appear. The specific gravity, however, seems to increase approximately as the iron oxide increases; and, except for Closeburn, the weathering power increases approximately as the lime and magnesia decrease. The percentage of iron oxide is lowest in Corncockle stone and highest in Corsehill. The specific gravity is above the average in Closeburn, Locharbriggs, and Gatelawbridge, but is fairly high in all. The crushing strength is highest in Corsehill and lowest in Ballochmyle, and is slightly below the average for sandstone. The percentage of alumina is highest in Closeburn and lowest in Locharbriggs. It is an undesirable constituent if over about 2 per cent. The absorption is above the average in the new red rocks, and seems to be most marked in Ballochmyle. A percentage of 9·5 has been obtained for Gatelawbridge, which is high. The value of 7·2 per cent. for Wemyss Bay is one of the highest among

Digitized by Google

other sandstones. They cease, however, to absorb water in most cases about two or, in most cases, three years after erection. This seems to be due probably to an alkaline silicate in the quarry sap, causing a deposition of silica when it comes to the surface, thus forming a natural preservative. From observation of buildings in Glasgow and elsewhere, it does not appear that this high absorptive power lessens the weathering resistance in the New Red Sandstones. They seem better adapted for a city atmosphere than any other sandstones ordinarily used, though it follows that the more water which gains access to a stone the more acid is able to act on the cementing material, on which really depends the quality of a stone; but the cement is in nearly all cases very stable. An important cause of decay in Glasgow atmosphere is sulphuric acid; the quantity is 80 per cent. over Liverpool, and 57 per cent. over that of Manchester. The red stones all resist dilute sulphuric acid remarkably well when tested. Machine-worked stone generally is more susceptible to weathering. The vibratory action of the tool may affect the molecular structure to a depth of $\frac{3}{8}$ inch, and the influence is often distinctly seen on the weather surface to a depth of $\frac{1}{8}$ inch.

Building.—The prevalent practice of building on "cant" is greatly to be condemned. There are hundreds of cases of bad weathering due to that alone. Many examples may be found in Glasgow, as at St. Vincent Street, Douglas Street, the County Buildings, Ardgowan Terrace in Sauchiehall Street, &c. The flakes of muscovite on edge indicate it at once.

Preservatives.—The essential point is to close up the pores, as by coating the stonework with paraffin oil in which a small quantity of paraffin wax has been dissolved. This was done at the Stock Exchange, Glasgow, then the sand blast applied to take away the dark colour. In the case of the Temperance League Buildings, built, in 1895, of Locharbriggs, the tops of the main projecting cornices were covered with Portland cement, 2 inches thick, to keep out the rain, and prevent disintegration of the bed. At Whitehill School, built of Corncockle, in 1893, the tops of the cornices were treated with oil paint. This initial treatment is to be highly recommended, especially with

Digitized by Google

porous stones. Flat surfaces should be avoided as far as possible, and all projections given a top slope, which may be coated with soda silicate or other preservative.

VII. Summary.

The following are the main conclusions to be derived from the paper:—

(1) The rounded grains of quartz, apparently wind-blown, the deep red colour of the grains, indicating general absence of organic matter, the abundant diagonal false bedding, and the labyrinthodont footprints of Corncockle are indicative of desert conditions during the formation of the sandstone.

(2) The available supply of New Red Sandstone is practically unlimited for many years to come.

(3) The presence of white rock among the red is due to the temporary ingress of particles of organic matter to portions of the lake, which reduced the peroxide of iron coating the sand grains. Variegated and poikilitic mottling, and banded spheres of decolorisation are due to chemical segregation.

(4) The sandstones are characterised by a bright brick-red to orange-red colour, a high percentage (91 to 98) of silica, a low percentage (0·2 to 2·63) of lime and magnesia compounds, a specific gravity varying from 2·06 to 2·6 (mean 2·24), a rather high absorptive power (9·5 per cent. highest), and a crushing strength on cubes of from 360 to 636 tons per square foot, the mean being under that for British sandstones. White sandstones have usually a higher crushing strength.

(5) The average mineral constituents are quartz grains, from ·005 inch to ·01 inch diameter, a few flakes of muscovite mica, a small amount of decomposing felspar, including plagioclase, orthoclase, and microcline sometimes fairly fresh, and iron ore, usually hematite, with occasionally doubtful biotite, calcite, and the rarer minerals kyanite, tourmaline, and apatite. They indicate derivation from the denudation of pre-existing Silurian igneous and granitic areas in the south of Scotland. With the exception of the Annan sandstones, there is a very marked petrological similarity. The latter are probably the youngest of the new red rocks.

Digitized by Google

(6) The cementing material is usually largely ferruginous, but may be wholly or partly argillaceous or partly of carbonates or siliceous matter.

(7) Crushing test specimens should have a minimum height of one and a half times the least width so that failure may take place on the proper angle, estimated theoretically as 57° to the horizontal for these sandstones.

(8) Building on "cant" is a more common source of decay than is supposed. Decay in the Glasgow atmosphere is largely due to the high percentage of sulphuric acid, which has little effect on the red sandstones. They seem to weather better than any other sandstones in the city atmosphere.

(9) The primary test of a building stone is the microscopic examination of a thin slice, and the elucidation of the petrographical structure by the chemical analysis.

The author is much indebted for information of a practical nature received from the late Mr. John Warnock, builder, Maxwelltown, and to the various quarrymasters for kindly supplying details of tests made on their sandstone.

EXPLANATION OF PLATE.

Fig. 1.—From Corrie Quarries, Arran.

This section is cut from a very good specimen, and contains quartz, with a little white mica. The dark crystals, like the one in the extreme north, are iron ore. The dusky matter in the west of the slide is decomposing felspar. There is a crystal of calcite in the north-west.

Fig. 2.—From near Auchinleck House (3 feet above base of sandstones).

The field shows numerous quartz grains in two sizes, and a few small thin crystals of white mica. A little in from the west side, there is an irregular dusky decomposing felspar. The dark crystals are iron ore, but some of the dark spots are carbonaceous material.

Fig. 3.—From Gatelawbridge Quarries.

There is quartz, muscovite, and iron ore, with a very little decomposed felspar, and some doubtful biotite. The dusky irregular matter is kaolin.

Fig. 4.—From Locharbriggs Quarries.

The section is very thin, and shows quartz, a little muscovite and iron ore, probably hæmatite. There are very few felspars in the field shown.

Digitized by Google

Fig. 5.—From Corsehill Quarries.

The left half is a section of white rock, and the right half of red rock. The sections are very similar, though the specimens were not located in close proximity. There are irregular patches of kaolinised felspar through the mass of quartz, and a few small muscovite mica crystals. There are some brownish crystals, perhaps originally biotite, which have given rise to iron ore.

Fig. 6.—From Quarries at Corncockle Muir.

The larger crystals, like the one at the top, are quartz. The small clear grains are quartz if rounded, and the dark ones iron ore or carbonaceous material. There is very little felspar, except in the cement, and as subordinate grains. There are a few flakes of muscovite.

Digitized by Google

APPENDIX.

CRUSHING TESTS.

For Messrs. LOWTHER, HALLIDAY & FORREST, LTD., Locharbriggs. By D. Kirkaldy & Son, London, 10th February, 1889.

TEST No.	NAME OF QUARRY.	DIMENSIONS.	Base Area.	CRACKED SLIGHTLY.			CRUSHED (Steelyard dropped).		
				Stress.	Per Square Inch.	Per Square Foot.	Stress.	Per Square Inch.	Per Square Foot.
		Inches.	Sq. ins.	Lbs.	Lbs.	Tons.	Lbs.	Lbs.	Tons.
270	Old Quarry, Locharbriggs, -	6·00 6·02 × 5·98	36·00	238,400	6,622	425·9	245,190	6,811	438·0
269	Do. do., -	6·00 6·00 × 5·95	35·70	219,800	6,157	395·9	228,320	6,396	411·3
271	Do. do., -	6·00 5·98 × 5·96	35·64	197,500	5,542	356·4	202,260	5,675	364·9
		Mean - -	35·78	218,567	6,107	392·7	225,190	6,294	404·7

Bedded between pieces of pine $\frac{3}{8}$-inch thick.

Digitized by Google

For Messrs. J. MURRAY & SON, Corsehill. By D. Kirkaldy & Son, 29th May, 1900.

TEST No.	DESCRIPTION.	DIMENSIONS.		Base Area.	CRACKED SLIGHTLY.			CRUSHED.		
					Stress.	Per Square Inch.	Per Square Foot.	Stress.	Per Square Inch.	Per Square Foot.
II.	All received 6-in. Cubes Ground.	Inches.		Sq. ins.	Lbs.	Lbs.	Tons.	Lbs.	Lbs.	Tons.
1561	Corsehill Quarry, Annan, Dumfriesshire,	6·00	6·02 × 6·00	36·12	394,000	10,908	701·5	394,000	10,908	701·5
1562	Do. Do.	5·94	5·91 × 5·90	34·87	351,500	10,080	648·2	351,500	10,080	648·2
1563	Do. Do.	5·96	6·00 × 5·95	35·70	309,800	8,678	558·1	309,800	8,678	558·1
				Mean	351,767	9,888	635·9	351,767	9,888	635·9

Bed surfaces prepared true.

Digitized by Google

For Mr. MARCUS BAIN, Ballochmyle. By D. Kirkaldy & Son, 14th February, 1905.

TEST No.	NAME OF QUARRY AND MARKED.	DIMENSIONS.		Base Area.	CRACKED SLIGHTLY.			CRUSHED.		
					Stress.	Per Square Inch.	Per Square Foot.	Stress.	Per Square Inch.	Per Square Foot.
N.N.		Inches.		Sq. ins.	Lbs.	Lbs.	Tons.	Lbs.	Lbs.	Tons.
294	Red Sandstone from Gatelawbridge Quarries, Thornhill, Dumfriesshire, 4 inch cubes,	3·76	4·06 × 4·02	16·32	117,400	7,194	462·6	124,500	7,629	490·6
296		3·89	4·10 × 4·06	16·65	110,900	6,661	428·4	111,600	6,703	431·1
295		3·96	4·04 × 4·02	16·24	99,800	6,145	395·2	99,800	6,145	395·2
				Mean	119,367	6,667	428·7	111,967	6,826	439·0
297	Do.	7·92	4·06 × 4·02	16·32	96,300	5,901	379·5	101,000	6,189	398·0
298	Do. Do.	7·95	4·08 × 4·00	16·32	94,200	5,772	371·2	94,200	5,772	371·2
299	4-in × 4-in. 8-in. high.	7·85	4·06 × 4·00	16·24	89,000	5,480	352·4	90,800	5,591	359·5
				Mean	93,167	5,718	367·7	95,333	5,851	376·2
302	Do.	11·98	4·06 × 4·06	16·48	99,900	6,062	389·8	99,900	6,062	389·8
300	Do. Do.	11·98	4·12 × 4·10	16·89	87,500	5,181	333·2	87,500	5,181	333·2
301	4-in. × 4-in. 12-in. high.	11·96	4·12 × 4·08	16·81	81,000	4,819	309·9	81,000	4,819	309·9
				Mean	89,467	5,354	344·3	89,467	5,354	344·3

Bed surfaces ground true.

Digitized by Google

For Messrs. THE SCOTTISH FREESTONE QUARRIES, LTD., Closeburn. By T. Hudson Beare, University College, London, W.C., 23rd November, 1900.

SHEAR TESTS.							CRUSHING TESTS.						
U.C.L. No.	Dimensions of Specimens.			Maximum Shearing Stress.		Remarks.	U.C.L. No.	Dimensions.				Crushing Tests.	
	a. inches.	*b.* inches.	Total Shear Area. Sq. ins.	Per sq. inch. lbs.	Per sq. foot. Tons.			*a.* Inches.	*b.* Inches.	Area Inches.	Height of cube. Inches.	Per sq. inch. Lbs.	Per sq. foot. Tons.
4323	2·028	1·022	4·15	2990	192		4335	3·000	3·000	9·000	3·000	8540	549
4324	2·027	1·016	4·12	2815	181	Plane of Shear at Right Angles to Plane of Quarry Bed.	4336	3·000	3·000	9·000	3·000	7140	459
4325	2·020	1·020	4·12	2720	175		4337	3·009	3·011	9·061	3·000	6892	443
4326	2·028	1·030	4·18	1850	119		4338	3·014	3·019	9·100	3·015	6216	400
4327	2·029	1·020	4·14	2234	144		4339	3·0105	3·010	9·063	3·020	6508	418
4328	2·020	1·013	4·09	2200	141·5		4340	3·009	3·004	9·040	3·015	8134	523
4329	2·025	1·018	4·12	2940	189		4341	3·012	3·013	9·075	3·015	8995	578
4330	2·010	1·025	4·12	2780	179		4342	3·009	3·008	9·051	3·015	7060	454
4331	2·012	1·026	4·13	3177	204	Plane of Shear across the Plane of Bed.							
4332	2·010	1·027	4·13	3370	217								
4333	2·025	1·028	4·15	3250	209								
4334	2·009	1·007	4·05	3308	213								

Bed faces made perfectly parallel.

The blocks were 8-in. long, and faces perfectly parallel.

Digitized by Google

For Messrs. THE SCOTTISH FREESTONE QUARRIES, LTD., Closeburn. By Prof. Stanfield, Heriot-Watt College, Edinburgh, 11th October, 1900.

2¼-inch cubes tested on	No.	Area of pressure face, sq. inches.	Crushing Load. Lbs. per sq. inch.	Tons per sq. foot.
bed, coated with thin	1179	5	9744	626
layer of plaster of	1180	5	7795	501
Paris, and scraped	1181	5	8557	550
parallel, - - -	1182	5	7280	468
	Average,		8333	536

BALLLOCHMYLE RED SANDSTONE. By D. Kirkaldy, London.

		Tons per square foot.
Height, 6 inches,	Cracked,	336·9
	Crushed,	360·0
Height, 12 inches,	Cracked,	325·0
	Crushed,	337·9
Height, 18 inches,	Cracked,	311·2
	Crushed,	321·9
Height, 24 inches,	Cracked,	273·7
	Crushed,	286·7

NOTE.—The stones were tested on the beds, and between pieces of pine ⅜-inch thick

Digitized by Google

SPECIAL MEETING TO CELEBRATE THE JUBILEE OF THE SOCIETY,

HELD IN THE GLASGOW UNIVERSITY ON THE 28th JANUARY, 1909.

At a meeting of the Society held in the winter of 1908 it was resolved that the Jubilee year of the Society should be celebrated in some manner befitting the importance of the event. A Committee was appointed to consider the form that the celebrations should take and to make all the necessary arrangements in connection with them.

After considerable discussion it was resolved that a volume should be issued giving a detailed history of the Society for the past fifty years, an outline of the work that had been done by the members of the Society in the different branches of geological investigation during that period, and a series of biographical notices of the more prominent members. It was also agreed that a conversazione be held about the beginning of the year 1909, to which the members of the Society and their friends, as well as delegates from British and foreign societies, should be invited. Both these objects were duly accomplished.

The Jubilee volume, entitled "The History of the Geological Society of Glasgow, 1858-1908, with Biographical Notices of Prominent Members," edited by the Hon. Secretaries, Mr. Peter Macnair, F.R.S.E., F.G.S., and Mr. Frederick Mort, M.A., B.Sc., F.G.S., F.R.S.G.S., was issued in the beginning of the year to each member of the Society. Copies were also sent to all the societies with which we exchanged our *Transactions*.

The Jubilee volume bears the following preface:—"This volume has been issued to commemorate the Jubilee of the

Digitized by Google

Geological Society of Glasgow. In the first chapter is given a brief sketch of the geology of the Clyde Valley, and notices of some of the earlier workers in this field. We are indebted to Mr. A. C. White for much of the material relating to the life of John Craig. The second chapter, dealing with the origin and early history of the Society, has been reprinted from the paper by Mr. Thomas M. Barr in vol. vii. of the *Transactions*. Chapter III. gives an account of the principal events that have taken place in the history of the Society since its foundation in 1858. The following five chapters give a summary of fifty years' work in the various departments of geological inquiry that have been pursued by the members of the Society. The titles and authors of the various chapters are as follow:—"Physical and Dynamical Geology," by Professor J. W. Gregory, D.Sc., F.R.S.; "Stratigraphical Geology," by Mr. Peter Macnair, F.R.S.E., F.G.S.; "Palæontological Geology," by Mr. James Neilson; "Mineralogy and Petrology," by Mr. Joseph Sommerville; "Glacial Geology," by Mr. John Smith; chapters ix., x., and xi. contain biographical notices of some of the Society's more prominent members. The notices have been contributed by Professor Gregory, Dr. John Horne, F.R.S.; Mr. Joseph Sommerville, Mr. Robert Dunlop, Mr. William Jolly, Mr. John Smith, and the Hon. Secretaries, Mr. Peter Macnair, F.R.S.E., F.G.S., and Mr. Frederick Mort, M.A., B.Sc., F.G.S. The index has been compiled by Mr. J. W. Reoch."

The conversazione was held in the University on the evening of Thursday, 28th January, 1909.

The principal feature of it was an address by Sir Archibald Geikie, K.C.B., President of the Royal Society, and now the senior member of the Glasgow Geological Society. The guests, a large and representative company, were received in the Hunterian Museum by Principal Sir Donald MacAlister, K.C.B., and Lady MacAlister, Sir Archibald Geikie, Professor Gregory (President of the Society), and Dr. B. N. Peach. While the company were assembling in the Bute Hall an organ recital was given by Mr. A. M. Henderson. Shortly after eight o'clock Professor Gregory ascended the rostrum, accompanied by Sir Archibald Geikie and Sir Donald MacAlister. Lord Provost M'Innes Shaw and Mrs. M'Innes Shaw occupied places on the

Digitized by Google

daïs, where also were seated the delegates from the following societies:—

Accademia dei Lincei, Rome,	Sir Archibald Geikie, K.C.B., P.R.S.
Société Linnéenne de Normandie,	,, ,,
Academy of Natural Sciences of Philadelphia,	,, ,,
New York Academy of Sciences,	,, ,,
University of Manchester,	Prof. Boyd Dawkins, F.R.S., D.Sc.
Manchester Geological and Mining Society,	,, ,,
Geological Society of London,	Dr. J. J. H. Teall, F.R.S., Director-General of Geol. Survey of Britain.
Royal Geographical Society,	Principal Sir Donald MacAlister, K.C.B.
Cambridge Philosophical Society,	Mr. W. G. Fearnsides, M.A., Sidney Sussex College.
American Philosophical Society,	Principal Sir William Turner, K.C.B., F.R.S.
Nova Scotian Institute of Science,	Professor James Gordon MacGregor, F.R.S., D.Sc., LL.D.
Institution of Mining and Metallurgy,	Dr. F. H. Hatch, M.I.C.E.
Geologists' Association,	Prof. W. W. Watts, F.R.S., Sc.D., Imperial Coll. of Science, London.
Manchester Literary and Philosophical Society,	Mr. D. M. S. Watson, Manchester University.
Natural History Society of Northumberland, Durham, and Newcastle,	Rev. Arthur Watts.
Berwickshire Naturalists' Club,	Dr. Robert Shirra Gibb.
Manchester Geographical Society,	Mr. J. Howard Reed.
Liverpool Geological Society,	Mr. Broderick.
U.S. Geological Survey,	Professor W. M. Davis.
Royal Physical Soc. of Edinburgh,	Dr. R. H. Traquair, F.R.S.
	Professor Graham Kerr, F.R.S.
	Mr. Lionel W. Hinxman, F.R.S.E.
Royal Scottish Geographical Soc.,	Mr. Lionel W. Hinxman.
Royal Society of Edinburgh,	Dr. John Horne, F.R.S., Director of the Geol. Survey of Scotland.
	Dr. R. H. Traquair, F.R.S.
	Dr. B. N. Peach, F.R.S.
	Mr. James Currie, M.A., F.R.S.E.
Geological Society of Edinburgh,	Mr. C. T. Clough, M.A.
	Mr. H. M. Cadell.
National Museum, Rio de Janeiro,	Mr. J. Mutter.
Geological Society of Hull,	Mr. Walter Dixon, F.R.M.S.

The Society was represented on the platform by the following office-bearers:—Professor J. W. Gregory, President; Mr. Joseph Sommerville, Mr. James Neilson and Mr. John Renwick, Vice-Presidents; Mr. J. W. Dron, Mr. John M'Kellar, Mr. James Stark, Mr. Robert Boyle, Mr. David Chalmers, Mr. Robert Dunlop, Mr. A. Macintyre, Mr. G. W. Tyrrell, Mr. C. R. Cowie, Mr. E. W. Gemmell, Mr. J. W. Reoch, Mr. M. Monie—members of Council; Mr. Peter Macnair, Mr. Frederick Mort, Hon. Secre-

Digitized by Google

taries; Mr. E. Hall Wight, Hon. Treasurer; and Mr. William Sinclair, Hon. Librarian. The following address was presented by Dr. J. J. H. Teall, F.R.S., on behalf of the Geological Society of London:—

To the President, Council, and Members
of the Geological Society of Glasgow.

The President and Council, acting on behalf of the Geological Society of London, send you their hearty congratulations on the occasion of your first Jubilee.

During the fifty years of your existence you have enrolled as active members of your Society not only men like Lord Kelvin and Sir Archibald Geikie, whose names are household words throughout the civilised world, but also a large number of resourceful investigators, such as Dr. John Young, of the Hunterian Museum, Mr. James Armstrong, Dr. David Robertson, Dr. William Grossart, and others whose publications in your *Transactions* and elsewhere have added greatly to our knowledge of the geology of your native land.

In offering to you our congratulations on your distinguished career in the past, we look forward with confidence to the future, persuaded that by your energy and perseverance you will contribute very largely to the general progress of our science, and especially to the solution of many of the perplexing problems of Scottish geology.

(Signed) J. J. H. Teall,
Delegate.

21*st January*, 1909.

Professor Boyd Dawkins, F.R.S., presented the following address on behalf of the University of Manchester:—

To the Geological Society of Glasgow.

The University of Manchester sends greetings and hearty congratulations to the Geological Society of Glasgow upon the completion of fifty years' scientific work. Founded in the year ever memorable for the publication of the "Origin of Species," your Society has had the advantage of carrying on its work under the stimulating influence of Darwin's researches and theories, and also in close proximity to the great University which so long numbered Lord Kelvin amongst its teachers. The *Transactions* of your Society with which the names of Sir

Digitized by Google

Archibald Geikie, Dr. John Young, Dr. Henry Woodward, Dr. Traquair, Mr. James Croll, and other distinguished men have been associated have both added to knowledge and aided in bringing scientific truths home to the people of the great city in which your Society is placed.

The Senate and Council, therefore, of the University of Manchester, recognising the importance of the work done during the past fifty years, desire to convey to the Geological Society of Glasgow their good wishes for the continued prosperity of the Society.

(Signed) ALFRED HOPKINSON,
Vice-Chancellor.
EDWARD FIDDES,
Registrar.

20th January, 1909.

Professor Dawkins also presented the following address from the Manchester Geological and Mining Society:—

MANCHESTER GEOLOGICAL AND MINING SOCIETY.
Instituted 1838.
(Federated with the Institution of Mining Engineers.)
Queen's Chambers,
5 John Dalton Street, Manchester.

TO THE GEOLOGICAL SOCIETY OF GLASGOW.

The Council of the Manchester Geological and Mining Society send their cordial congratulations to the President, Council, and members of the Geological Society of Glasgow on the celebration of their Jubilee. The two Societies have been in touch with each other since the year 1859 by the exchange of publications, and we in Manchester are deeply sensible of the value of the work done in Glasgow by our younger sister.

Among the illustrious contributors to the *Transactions* of the Geological Society of Glasgow the names of Craig, Croll, Geikie, Kelvin, Traquair, and Young stand for the high quality of the additions made to the knowledge of the ancient history of the earth.

For these reasons the Manchester Geological and Mining Society have appointed Professor W. Boyd Dawkins, M.A., D.Sc., F.R.S., F.G.S., their delegate to convey their sentiments and their belief that the good work done in the past by the

Digitized by Google

Geological Society of Glasgow will be carried on with unabated energy in the future.

Dated this 23rd day of January, 1909.

(Signed) LEES KNOWLES, Bart.,
President.
SYDNEY A. SMITH,
Hon. Secretary.

A large number of telegrams and letters were received congratulating the Society upon its having attained its Jubilee year.

In his opening address the President, Professor J. W. Gregory, said the Geological Society of Glasgow had been fortunate in its roll of distinguished members. For twenty-two years Lord Kelvin was their President. The name which had been longest on their list of members was that of Sir Archibald Geikie. In 1862 he read to the Society a paper which occupied three-fourths of the first volume of their *Transactions*, and which at once lifted British glacial geology on to a new plane. Sir Archibald therefore started their *Transactions* on a very high level, and now, as President of the Royal Society, the official head of British science, he came to address them again. Sir Archibald Geikie was sure of a warm welcome from any Scottish audience. They awaited with impatience his judgment as to how far their Society had lived up to the standard he set forty-six years ago.

Sir Archibald Geikie then delivered his address.

Digitized by Google

THE PIONEERS OF GEOLOGY IN THE GLASGOW DISTRICT.

An Address given at the Jubilee of the Geological Society of Glasgow on 28th January, 1909.

By Sir ARCHIBALD GEIKIE, K.C.B., Pres. R.S.

Throughout the compass of the British Isles few places present such an excellent field as Glasgow for varied and interesting geological pursuits. Even within the municipal boundaries, and at short distances beyond them, the geologist finds material inviting his attention, while the multiplied facilities provided by modern conveniences of locomotion have so enlarged his field of observation as to make this a centre of singular attractiveness. To the north and west, within sight of the higher parts of the city, the long range of the Highland hills rises up against the sky, and at the end of a brief journey by railway or by steamboat we may place ourselves among the oldest rocks in the district—the foundation-stones on which the framework of the southern half of Scotland reposes. There, amidst the silence of the glens and moors, and face to face with the very rocks themselves, we may ponder over the many problems presented by the array of the crystalline schists. On the flanks of these hills we may climb the vast heaps of conglomerate, which, out of the secular waste of the Highlands, were laid down in the waters of Old Red Sandstone time. There, too, we may follow the course of the great fracture in the crust of the earth whereby the so-called "Highland line"—the boundary between the mountains and the Lowlands—was defined long ages ago. On either side of the Clydesdale valley the terraced heights of the Campsie and Kilpatrick fells, and those which stretch from Gourock to Strathaven, appeal to us as monuments of one of the great periods of volcanic

Digitized by Google

activity to which Scotland owes so much of what is most prominent in her Lowland scenery. Beneath our feet lie the memorials of the seas and lagoons and jungles of the Carboniferous period, teeming with the remains of ancient living things. And, to crown all, wheresoever we may turn, our eyes meet with the records of that strange "ice age," which had probably not quite passed away when the earliest human population made its way into this western limit of the European Continent in pursuit of the mammoth, the reindeer, and the musk ox. In short, every step in our excursions brings us to objects fitted to arrest attention and to appeal powerfully to the imagination, by revealing through what a marvellous series of mutations of land and sea the scenery around us has been slowly fashioned into its present familiar forms.

With such advantages for observation geology might be expected to have sprung up here in early days, and to have always counted a large company of zealous devotees in Glasgow. It may therefore be matter for surprise that not until some fifty years ago did the number of those who followed a geological bent grow large enough to call for the formation of a Geological Society. Nevertheless, the geology of this interesting district had by no means been neglected before that time. It had been till then studied, however, almost wholly by strangers from other parts of the country, and even from abroad. For more than half a century a succession of these visitors wandered over all parts of the area and published their observations, before native enthusiasm for the subject was fully aroused. I have thought that it might be a suitable subject for the present occasion were I to lay before you a brief and necessarily incomplete outline of what was done by these early pioneers who led the way for us, and to offer some reminiscences of a few of those among them whom I have myself personally known.

It is a curious fact that some of the earlier writers on Scottish geology were foreigners, some of them attracted to this country by the fame of the wonders of Staffa and the Western Isles, which had first been made known to the world in 1774 by the description of Sir Joseph Banks. One of the earliest and most celebrated of these visitors was the Frenchman, Faujas de Saint-Fond, who, in the year 1784, travelled all the way from the south of France to see the marvels of Fingal's Cave

Digitized by Google

and its surrounding colonnades of basalt. He was a singularly ardent student of geology, more particularly of the volcanic section of the science. He had recognised the volcanic origin of the rocks of his native Vivarais, at a time when few observers were yet competent for such a task. When he came to Scotland he found here memorials of what he considered to have been once active volcanoes. His observations at Glasgow have a special interest for us in this Society. He believed that he had met with evidence of true lavas here, and he made a list of the various rocks which he had observed. But, having neither guide nor map, he gave no precise indications of the actual localities from which his specimens were obtained. It might be of interest, however, to see whether from the indefinite indications given by him some, at least, of his sites could even yet be localised, and perhaps some members of the Glasgow Geological Society might be induced to attempt this search. After sundry adventures by the way, he succeeded in reaching Staffa, on which island he was the first geologist to set foot. He gave an account of his journey in two graphic and entertaining volumes, which appeared at Paris in 1797, and were translated into English two years later.[1] An enterprising and public-spirited bookseller of Glasgow, Mr. Hugh Hopkins, has recently published a revised edition of the English version, which may be recommended to any reader who wishes to have a vivid and amusing picture of travelling in Scotland towards the end of the eighteenth century.

On his way back from the West Highlands Faujas de Saint-Fond passed through Edinburgh, and met there the illustrious James Hutton, who, he tells us, "was at that time engaged, in the calm of his study, writing a work on the 'Theory of the Earth.'" Little could the French traveller have divined that "this modest philosopher," as he calls him, would in after years be universally acclaimed as one of the great founders of modern geology, and that the treatise on which he was then at work, and which was communicated a few months later to the newly founded Royal Society of Edinburgh, would take its

[1] "Voyage en Angleterre, en Écosse et aux Iles Hébrides," par B. Faujas-Saint-Fond, 2 vols., 8vo, Paris, 1797. The revised English version is entitled "A Journey through England and Scotland to the Hebrides in 1784," 2 vols., 8vo. Glasgow: Hugh Hopkins, 1907. It contains a memoir and portrait of the author.

Digitized by Google

place as one of the classics of geological literature. During the next ten years Hutton was sedulously employed in gathering from different parts of Scotland further detailed evidence in support of the general principles which had been laid down in this first outline of his theory. In the course of these excursions, as he has himself put on record, he had often, from the heights of eastern Lanarkshire, looked with admiration on the far-distant peaks of Arran, feeling convinced that their Alpine recesses would yield fresh illustrations of the structure and origin of mountains. Among the geological treasures of the Glasgow district there is surely none so precious as the possession of that incomparable island. How many geologists in successive generations have made their pilgrimage to its shores, and have learnt there some of the most vivid and suggestive lessons in their experience! As myself one of that band of pilgrims, I may perhaps be allowed gratefully to acknowledge how much I owe to these early lessons. While still a boy I was offered the choice of visiting the Great Exhibition of 1851 or of making a geological excursion. I chose to spend some weeks in Arran, and I can vividly recall how the glamour of the island fascinated me, and how from its glens and crags and shores there came to me an impetus that shaped my career and has remained potent with me ever since.

It was not until the summer of 1787 that Hutton was able to visit Arran. Once there, he seems to have fallen immediately under its spell. He was so captivated by its geological attractions as to be led on to traverse its length and breadth, until he had grasped its general structure, and was able to describe the prevalent characters and broader relations of its component rocks. He wrote a detailed account of his examination of the island, which he intended should be one of the chapters in the third volume of his enlarged work on the "Theory of the Earth." Unfortunately he did not live to publish that volume. The manuscript, which is said to have been left "nearly ready for the press," disappeared, all save six chapters, which ultimately came into the possession of the Geological Society of London, in whose keeping they remained undisturbed for more than forty years. At last, in 1899, the Council of the Society, at my suggestion, published this precious relic. Had the chapter descriptive of Arran, which, fortunately, formed part

Digitized by Google

of the surviving manuscript, appeared in the author's lifetime, it would have been the first general account of the geology of the island, and it would have added greatly to his scientific reputation among his contemporaries. For it shows him to have been no mere theorist, as some of his opponents maintained, but a shrewd, painstaking, and accurate observer, who with intuitive genius saw the meaning of details which it was left for his successors in later years to interpret as he had done. Yet he never suffered himself to be lost amid details, always keeping his eye steadily fixed on the elucidation of the fundamental problems which they could be made to illustrate. No one can ramble over Arran, Hutton's chapter in hand, without having his admiration for this great master confirmed and increased.

Hutton's study of Arran was of service to him in the development of his views concerning the structure of the earth's crust and the processes by which the surface of the land is changed. Though his full account of the island was not published by him, he made use of some of his observations in the two volumes of his "Theory of the Earth," which were given to the world in 1795.[2] One of these observations is that relating to the now well-known section on the shore near the mouth of Loch Ranza. He remarks that, after having long searched for any exposure of the junction of the Highland schists with the Lowland strata, he discovered it for the first time at that place, and found that it completely confirmed his anticipations. He was a man who did not repress his emotions on such occasions. We can well believe that his delight over this discovery was as visibly shown as when he found the granite veins in Glen Tilt, where his Highland guides thought, from his excitement, that he must have come upon a vein of silver or gold. On that Loch Ranza shore the section of the upturned ends of the schists, wrapped round by the breccias and sandstones, presents a striking example of what is now known as an "unconformability," but it has acquired an added interest to all students of geology from its having rewarded the search of the author of the "Theory of the Earth," and having been described by him.

[2] Vol. i., pp. 429, 467, 480.

Digitized by Google

Some of the little personal touches in the Arran chapter afford us glimpses of Hutton's eager and enthusiastic nature. Thus he tells how, when he and his companion, John Clerk, younger of Eldin, were searching for the actual junction of the granite and schist on the southern shoulders of Goatfell, "having once got hold of the clew, or catched the scent, we traced back, with more animation than could have been expected from such an innocent chace, the object of our investigation, all the way to the very place from whence we had set out, at the head of the Cataract rock."[3] Again, when they were exploring the northern crags of the same mountain, he remarks, "Our curiosity in examining this dyke tempted us to slip down this place in descending the mountain into the high Cory Glen, an idea which could not have entered the head of any sober person who was not a mineralist."[4]

In Arran Hutton found abundant evidence of the two great classes of igneous and sedimentary rocks, out of which, as he maintained, the visible crust of the earth is built up. The serrated crests of this island, at which he had so long and so wistfully gazed from a distance, furnished him with irresistible demonstrations of the intrusive nature of granite, while the hundreds of "whinstone" dykes all over the ground bore welcome testimony to the truth of his doctrine of "subterranean" or "unerupted lava." The crumbling crags on the ridges and the long screes shelving down into the glens below, together with the conspicuous proofs of the demolition wrought by the sea along the coasts, vividly impressed him in confirmation of his contention that the universal decay of the surface of the land is a necessary part of the economy of Nature. We members of the Glasgow Geological Society, to whom Arran is so dear, thus derive an added gratification from the thought that the contemplation of its surface influenced the father of modern physical geology, and that he derived from its glens fresh evidence that valleys have been slowly carved out of the rocks by the subærial agents which are still engaged in the same task.

A few years after the publication of Hutton's immortal work in 1795, Arran was the subject of description by another and

[3] Vol. iii., p. 225.
[4] Vol. iii., p. 248.

Digitized by Google

very different type of observer—no less a person than Robert Jameson, the great champion of Neptunism in this country, and at that time the uncompromising adversary of Hutton and the Vulcanists. The warfare between these two opposing schools, which was in progress on the Continent, was then beginning to grow active also in Britain. Hutton himself had passed away in 1797, but his friend Playfair took up the defence of his doctrine, and published his charming "Illustrations of the Huttonian Theory" in 1802. Jameson, as a convinced Neptunist, could find in Arran nothing but rocks that had all been deposited from water. His account of his examination appeared in the year 1800 as part of the record of a tour made by him through the Inner Hebrides, the Orkney and Shetland Isles, and across various parts of the mainland of Scotland.[5] I know no more curious and melancholy contrast in geological literature than is presented by this essay placed alongside that of Hutton. Jameson's chapters are little more than mere dry and dreary topographical enumerations of the various species of rock which he had met with, interspersed with frequent references to those geologists who would not follow Werner, and whom he contemptuously denominated "forlorn fire-philosophers." In his account of Arran he indulges in frequent carping criticism of Hutton. Thus he quotes at length the eloquent passage in the second volume of the "Theory of the Earth," which depicts the successive stages in the slow process of waste whereby portions of the mainland are cut off into islands by the ceaseless attacks of the sea, and which insists on the vast lapse of time that must have been required before the present indented condition of the margin of the land could have been reached. The nature of Jameson's comments may be judged from his remarks on this quotation. Hutton's doctrine, he admits, gives "probably a correct delineation of the mode which Nature follows in altering the land; but it cannot be general, as it would give an age to the world quite inconsistent with the Hebrew chronology; we must therefore consider it as untenable." He prefers to look upon the isolation of masses of land as evidence of a time when "this country was convulsed by earthquakes."[6]

[5] In a work entitled "Mineralogy of the Scottish Isles," in 2 vols., quarto. Edinburgh, 1800.

[6] *Op. cit.*, vol. i., p. 138.

Digitized by Google

Seven years after the appearance of Jameson's volumes another mineralogical description of Arran was published by a disciple of the Neptunist school, James Headrick. It is little more than an account of the topographical occurrence of the different varieties of rock met with by the author in his traverses of the island, but with fuller details than were given by Jameson. Though he professed that his " object is to collect facts and leave to future Naturalists to point out their reason and cause," he could not resist the temptation to indulge in uncomplimentary references to the Huttonians of his day, whom he styles " fiery philosophers," " men of fire," and " igneous theorists." He appeals to them, " if they are not too hot to give a cool answer." Constantly assailing what he calls " the igneous theory," he proclaims his belief that basalt was " originally a muddy deposite which consolidated and split into columns by slow drying, and not by slow cooling," and he maintains that " basaltic veins have been formed from matter conveyed into cracks and fissures of the strata from above."[7]

Further evidence of the prevalence of the Neptunist creed in Scotland at the beginning of last century is supplied by the papers of a staunch ally of Jameson, Dr. Thomas MacKnight, who made various excursions into the Glasgow region, of which he published the fruits in the earlier volumes of the " Memoirs of the Wernerian Society." They breathed the true, narrow Wernerian spirit, and although they made known for the first time the occurrence of various rocks in different parts of the country, they were of but little consequence as elucidations either of the structure of the country or of geological theory. Their value may be gauged from his paper on Cartland Crag—a locality which he cites as an *experimentum crucis* " to decide the faith of mineralogists," as between the two rival doctrines of the Neptunists and Vulcanists. Reviewing the evidence, he pronounces in favour of the " aqueous theory."

In the year 1819 there appeared the monumental " Description of the Western Islands of Scotland," by John Macculloch, which, emancipated from the Neptunist dogmas and breathing the free, bold spirit of the Huttonian philosophy, marks a

[7] " View of the Mineralogy, Agriculture, Manufactures and Fisheries of the Island of Arran." By the Rev. James Headrick. 1 vol., 8vo. Edinburgh, 1807 (see pp. 111, 112, 123, 171, 217, 218).

Digitized by Google

notable epoch in the progress of Scottish geology. The only portion of this remarkable work, however, that need be noticed here is its excellent account of the Clyde islands, which may be regarded as the foundation whereon all subsequent descriptions of these islands have been based. The author was an acute observer, gifted with a firm grasp of field geology, and a literary faculty of no common order, which enabled him to present the results of his investigations in clear and attractive form. Later writers have filled in many details which escaped his notice and have corrected many errors into which he fell, but his work will always command respect as a valuable contribution to the progress of geological science.

Contemporary with Macculloch was another observer to whom Scottish geology stands deeply indebted, and about whom, as I knew him personally, I have already published some account, but I may appropriately give a few particulars in this place.

Ami Boué, whose parents were Swiss, but of French descent, was born in Hamburg in 1794. As he grew out of boyhood, the French armies were overrunning Europe, and his parents, fearing that in those troublous times the family property, which consisted chiefly of houses in Hamburg, might be destroyed, determined to place him in the safest corner they could find, where he might learn a profession on which he could fall back should the necessity arise. In the end they sent him to study medicine at Edinburgh, and supplied him with good introductions into society there. He used to say that he went to Scotland to be out of the way of Napoleon. He took his degree of M.D. at Edinburgh in the year 1817. By that time, however, Napoleon had fallen, and Hamburg was safe. Hence, as there was now no necessity for the young doctor to take up the medical profession, he was at liberty to follow the scientific pursuits which had by this time become his chief interest. During his college career at Edinburgh he cultivated botany, of which he used to say that he knew more than his professor. He studied under Jameson, whose lectures embraced the wide domain of Natural History. Boué soon addicted himself more especially to what was then called "geognosy," but, while he profited by the professor's local knowledge of the distribution of rocks and minerals in Scotland, he seems somehow to have been immune to the virus of Wernerism. He

Digitized by Google

spent his holidays in rambling over much of Scotland, hammer and notebook in hand, selecting preferably the districts where volcanic rocks occur, and recognising these rocks as true products of igneous agency. The voluminous notes of his observations which he made on those journeys were written in French, which was the language of his mother. In Hamburg he had, of course, acquired a knowledge of German, and during the years he spent in Scotland he learnt to read English, and to speak and write it after a peculiar fashion. But he went through life without a language which he could call his native tongue, or which he could consistently use with perfect correctness.

Leaving Scotland after taking his degree, he went to Paris, where for a time he employed himself in preparing a detailed account of the geology of Scotland. But he started on his travels in Europe before the book was published. It appeared in his absence, with various typographical errors, and as he was wont to complain, with the stupid omission of any date on the title-page.[8] It really saw the light in the year 1820. As a compendium of Scottish geology this volume had extraordinary merit. It gave a succinct account of the work of previous writers and innumerable original observations by the author himself. It contains abundant references to the Glasgow district. More especially valuable and far in advance of the time was his recognition of the volcanic origin of the plateaux, such as the Campsie Fells, and the Ochil and Pentland Hills. He was taught in the class-room at Edinburgh University that these tracts, as well as the numerous basaltic eminences of the central Lowlands, were all the results of precipitation from the primeval ocean. But Boué's eyes recognised their true nature, and he pursued their study as the products of volcanic activity, being thus the first geologist to realise from extended personal research that volcanic eruptions have played a large part in the geological history of Scotland.

He never returned to this country after his student days here. He used to confess that he was afraid of a climate in which he had always been forced to encase himself in flannel. He

[8] "Essai Géologique sur l'Écosse," par A. Boué, Docteur en Médecine, Membre de la Société de Médecine d'Edinbourg, de la Société Wernérienne, et de celle d'Histoire naturelle de Genève. Paris. [No date.]

Digitized by Google

travelled far and wide on the Continent, his journeys in Turkey being especially memorable, for his account of them gave the first description of the geology of an extensive region of South-Eastern Europe. He wrote many papers; also an excellent handbook for the guidance of the geological traveller. He was one of the principal founders of the Geological Society of France. His later years, after his wanderings had come to an end, were spent by him in Austria. During the winter he lived in Vienna, and he passed the summer in a pleasant country retreat, which he had made for himself on the last spur of the Alps as they sink into the plain of the Leitha. There, among his books and papers, he kept up his interest in the progress of Scottish geology. It was in consequence of a reference to his "Essai" in some paper of mine which he had seen in one of the journals of the day that he wrote to me, and that I became aware that he was still alive and interested in the scenes of his Scottish sojourn. At his invitation I paid him a visit in 1869, and made excursions with him in the district around Vienna and Vöslau. For a number of years we exchanged letters. Boué's were always written in his characteristically broken English and in a minute, hardly legible handwriting, with its closely set lines striking diagonally across the page. I have elsewhere given an illustration of his epistolary style by quoting from a letter which he sent to me in November, 1870, during the gloomy time of the Franco-German war, wherein he remarks that he had "very good and near parents in both armies," and laments the possibility of "parents killing themselves without knowing themselves, nor having the opportunity to do so."

Boué wrote a little autobiography in which he gave an account of the experiences and adventures of his life, leaving a blank for the date of his death. He addressed copies of this printed pamphlet, with instructions that they should be sent to his friends when he no longer lived. My copy, addressed in his well-known handwriting, which duly reached me by post towards the end of November, 1881, was his last communication to me.

None of the observers to whom I have referred as the earliest writers on the geology of this district lived within its bounds. Their published books and papers were long in awakening any

Digitized by Google

geological ardour here. Nevertheless, a few native inquirers began to make their appearance during the closing years of the eighteenth and the early decades of the nineteenth century, as pioneers in the investigation of the details of the local geology. First came David Ure, whose excellent "History of Rutherglen and East Kilbride," published in 1793, stands out pre-eminent for the fulness and faithfulness of its descriptions. It was the earliest contribution to the palæontology of the Carboniferous rocks of Scotland. David Landsborough appeared later, and by his enthusiasm as a naturalist and the abundance, variety, and excellence of his original contributions to the zoology and botany of the Clyde basin, well deserved the name applied to him—the Gilbert White of the West of Scotland. He included geology within the wide range of his interests, and co-operated with Smith of Jordanhill in the examination of the upraised shell-beds of the Clyde, but perhaps his claim to be included in a series of geological worthies may be most fittingly based on the share which, in conjunction with Professor J. P. Nichol, the astronomer, he had in launching upon a scientific career one of the most distinguished geologists that Scotland has produced—Andrew Crombie Ramsay. This admirable field observer was born in 1814. After trying a mercantile profession without success, he betook himself to Arran, where his family had been accustomed to spend their summer holidays. As the result of a long and detailed survey he was able to construct a large geological model of the island, and to write a singularly able detailed description of its geology.[9] The model was exhibited at the memorable meeting of the British Association, held here in the year 1840, and it excited much interest among the remarkable muster of geological chiefs who were then assembled. Young Ramsay at once found himself welcomed and appreciated by the leaders in his favourite science. Among those whose acquaintance he then made were De la Beche, the Director-General of the Geological Survey, and Murchison, about to prepare for his great journey through Russia. By the influence of these two powerful friends, Ramsay was appointed next year to the Geological

[9] "The Geology of the Island of Arran, from Original Survey." By Andrew Crombie Ramsay. Glasgow, 1841. It is an octavo pamphlet of 78 pages, with a Geological map, plate of sections, and text-figures, from drawings by the author.

Digitized by Google

Survey. In that service he remained for forty years, gaining a world-wide reputation as an accomplished stratigraphical geologist and suggestive writer on geology and physical geography. He rose to be Director-General on the death of Murchison, and retired from office at the close of 1881, when he received the honour of knighthood in recognition of his long and distinguished service.

It would be out of place to deal on this occasion with Ramsay's work while he was on the staff of the Survey, for it did not relate to the geology of the Glasgow district. Of his little volume on Arran, which was his earliest published essay, and the only contribution made by him to the geology of the Clyde, I need not speak here. It is familiar to all of us as one of the treatises which every student of the geology of Arran is proud to possess, if he has been fortunate enough to procure a copy, and it has served as a guide and a model ever since it was issued seventy years ago. But I may be permitted here to record my deep attachment to Ramsay as one of the most genial, large-hearted, and helpful friends I ever had. It was partly by his personal influence that I received an appointment in the Geological Survey, and I look back with the warmest feelings to his unwavering friendship during our long association in the public service. To be his companion in the field was itself an education. His conversation, always animated and often witty, ranged over all the problems of geology, which he discussed with a singularly suggestive originality. From these professional topics he delighted to break away into delightful discourse over some department of English literature, a subject of which he possessed a wide knowledge. Though his active life was spent at a distance from his native district, we remember with no little pride that he was born and educated here, and we feel that, as one of the best observers who have written on the geology of Arran, he may be justly claimed as a Glasgow geologist.

About the time that Ramsay was beginning to make his survey of Arran, John Craig was at work among the Carboniferous formations of the Lower Ward of Lanarkshire, of which he gave an interesting account that was published by the Highland Society in 1839. In Renfrewshire, Montgomery, about the same time, was engaged upon his essay on the geology

Digitized by Google

of that county, which appeared in the same volume with that of John Craig. It is well also to remember that during the first half of last century the progress of mineralogy and geology was helped forward here by Thomas Thomson, the professor of chemistry in the University. His numerous analyses of new minerals from Scotland and elsewhere were important original contributions to knowledge, while the second volume of his "Outlines of Mineralogy, Geology, and Mineral Analysis," published in 1836, furnished the student of the time with an able summary of what was then known in the domain of geological science. Nor should we omit to notice among the resident geologists of older standing James Bryce, whose earlier work in the north of Ireland had brought him into notice, and who, when he settled in Glasgow, proved himself to be one of the most enthusiastic and active pioneers of our Society. His little work on the geology of Arran and Clydesdale has long held its place as a helpful guide to the districts which it describes.

Of all the influences which have conspired to raise in Glasgow a general interest in the geological history of the district, I am disposed to give the foremost place to that of James Smith of Jordanhill. This admirable observer was born as far back as 1782. Possessed of ample means and leisure, he became a keen yachtsman and naturalist, and continued his cruises until past eighty years of age. His little yacht, flitting to and fro among the bays and harbours of the Firth of Clyde and its tributary sea-lochs, was as well known as any of David Hutcheson's fleet of steamboats. He took much interest in dredging up the various forms of life on the sea-bottom, and he had consequently become familiar with the shells living there. The story is well known of his ramble along the shores of the Kyles of Bute, how he came upon a number of shells which he had never found in any of his dredgings, how he set to work with increased zeal to discover whether any of them could still be found surviving in the neighbouring waters, and how at last he ascertained them to be northern forms, extinct in our seas, but still living in boreal and arctic latitudes.

The occurrence of elevated beds of sea-shells had long been known in this part of Scotland. As far back as the year 1822,

Digitized by Google

Adamson's discovery of the shell-beds on the shores of Loch Lomond was published in the "Memoirs of the Wernerian Society," together with Laskey's note of those detected by him on the southern side of the Clyde, a few miles to the west of Glasgow. But the importance of Smith's observations lay in their revelation of the presence of a group of shells, previously unrecognised here, and at first believed to be wholly extinct. His interest in the subject led him not only to examine the upraised marine clays on both sides of the Clyde estuary, but to extend his cruises into northern waters, in order that he might there obtain living representatives of the species that had died out in the Scottish seas. He drew the irresistible inference that at a comparatively recent geological period the climate of this country must have been colder than it is now. His discovery and the conclusions he deduced from it were communicated to the Geological Society of London in the spring of 1839, more than a year before Agassiz and Buckland proclaimed their belief that the British Isles had once been largely covered with ice. He was thus the first observer who brought forward indisputable evidence of that lowering of the general temperature of our latitudes, which is now confirmed by so many other proofs. And his deduction, based upon the clear testimony of organic remains, has stood its ground unchallenged, although so much controversy has arisen over other parts of glacial geology.[10]

After the lapse of half a century I can recall the genial presence of this most estimable man, his cheery welcome as one stepped on board of his yacht, his nautical costume, complete from the deck-shoes up to the cap, from under which his long, white locks hung over his neck, his still agile movement as he ushered one into his little cabin, the pride with which he pointed to the shelf that held the geological and natural history volumes, which were his companions on all his cruises, his racy talk over his experiences of the past, and his eager desire to hear all about the newest discoveries in post-Tertiary geology. He continued to follow this healthy seafaring life in summer, almost up to the end of his life, dying at the ripe age of eighty-

[10] In the year 1862 he reprinted his papers in a little volume entitled "Researches in Newer Pliocene Geology." Glasgow. Some of the papers originally published only in abstract are there given in full, with some notes added by the author.

Digitized by Google

four, universally respected and beloved. Among those whom this Society has delighted to honour, and who have thrown a lustre upon its history by filling its presidential chair, there is none so deserving to be held in lasting remembrance as James Smith of Jordanhill, the pioneer of glacial palæontology.

The seed sown by this worthy leader began in the course of years to spring up in this district, as was shown by the successive appearance of different observers who devoted themselves to the study of what were now known as "the Clyde beds." Among these labourers there was one whose name is hardly known, for although he was a competent and active investigator, he shrank from publishing the results of his researches. The Rev. Alexander Macbride, of North Bute, for many years in the course of his clerical journeys and during his summer holidays, devoted himself to tracing the glacial shell-bearing clays, not only along all the coast-line of his island home, but on both sides of the Firth and westwards across Argyllshire as far as the shores of Lochiel. He had detected the extension of these deposits far beyond the limits within which they were at first supposed to be confined. When I was preparing the material for my memoir on the Glacial Drift of Scotland, which was published in 1863 in the first volume of our Society's *Transactions*, this accurate and modest observer guided me over much of the ground which he had explored. In that memoir, which gave the first connected description of the whole series of glacial deposits, I acknowledged my indebtedness to Mr. Macbride, but I am glad of this opportunity of bringing his quiet and unobtrusive labours to the notice of geologists. His large store of varied knowledge was always at the service of others. He was an excellent Celtic scholar, a sound antiquarian, and a keen lover of scenery. My acquaintance with him ripened into intimate friendship, and many were the excursions which we made together into the West Highlands and Islands. My account of the glacial clays of the Clyde could not have been written but for the assistance which his wide local experience enabled him so generously to give me.

I derived help also from John Scouler, with whom I came into frequent and close contact. He preceded James Smith of Jordanhill in the presidency of this Society, and his prodigious stores of learning in almost all departments of human

Digitized by Google

knowledge were a constant source of wonderment, even to the friends who knew him best. To another early member of this Society, the late Rev. Dr. Crosskey, I was likewise indebted for assistance in my studies of the Clyde beds.

Looking back upon the history of the Geological Society of Glasgow, I think there can be little doubt that the most important service rendered by the Society to geological science is to be recognised in the contributions which it has published towards the investigation of the records of the Glacial period. It was natural and fitting that this should be so. In no part of Britain has the marine life of that interesting period been so fully preserved over so wide an area as in the sheltered basin of the Clyde, and it was here that this fascinating chapter of geological history was first opened out by Smith of Jordanhill. The succession of papers wherein the different portions of the glacial series are discussed in the Society's *Transactions* is one of which any learned society might be proud. I would more especially refer to the admirable memoirs by Crosskey and David Robertson on the post-Tertiary Fossiliferous Beds of Scotland, which appeared between 1867 and 1873. These will always be regarded as a monument of patient skill and accuracy, and as contributions of the highest importance in the interpretation of the history of the Glacial period.

It seems to me but yesterday since this Society was founded here by a handful of earnest and enthusiastic men. And yet, since then, half a century has slipped away, crowded with labour and discovery. As the oldest member of the Society I wish very heartily to congratulate my colleagues on the completion of this eventful period in the Society's history. The hopes and aspirations of our founders have been amply justified. We believe that the Society may confidently look forward to a future not less active and useful than the past has been. There need be no fear that the geology of the district has been almost completely worked out by the successive generations of observers who have explored it, or that in putting on record the results of their explorations they have left but little behind for future discovery. In the geological, as in other departments of inquiry, Nature is inexhaustible. At present many problems in the geology of the Clyde basin still await solution, and before these shall have been solved others will

Digitized by Google

have arisen to demand attention. The first broad outlines have been traced, but endless details remain to be investigated which will require prolonged and specialised research. Those of us whose age forbids them to have more than a distant vista of this promised land of the future have good reason to congratulate our younger successors on the prospect that lies before them. May the Geological Society of Glasgow long live as a vigorous centre of geological activity, may its membership and its resources steadily increase, and may its publications continue to maintain and to augment the reputation which they have already gained.

Sir Donald MacAlister, in moving a vote of thanks to Sir Archibald Geikie, said it was no small honour to them of the University, who had already celebrated nine jubilees, and to the Geological Society of Glasgow, which was celebrating its first, that their festival should be graced by the presence of the President of the Royal Society of London. Apart from his distinguished place as the official head of the greatest of British learned societies, the successor of Newton, Sir Archibald Geikie had many claims to their welcome and their gratitude. During a long and strenuous career he had added many a volume to their knoweldge of the earth's structure. He had in particular, by his personal labours in the field, solved many of the problems in the complex history of our own Scotland, and he had not only made new geology, but he had made geologists. The second and third generations of his scientific offspring were at that moment filling the chairs in our Universities, and filling to good purpose also the maps and the records of the Geological Survey and the volumes of the geological *Transactions* in every quarter of the globe. By length of high service and by primacy of personal achievement he was now the Nestor of his science. He was a Scot of the Scots. By birth, by nurture, by sympathy, by native capacity and native energy he was a true representative of that race, whose peculiar vocation it seemed to be ever and anon to be called upon to govern the three kingdoms for their moral and intellectual welfare.

Sir Archibald Geikie, in reply, said he looked back with the greatest interest on his association with the Society in its early days, and he gladly availed himself of the opportunity of taking part in its celebrations.

Digitized by Google

The President moved a vote of thanks to the delegates who had come to take part in the celebration.

Lord Provost M'Innes Shaw, in proposing a vote of thanks to the University authorities for having granted the hospitality of their buildings to the Geological Society of Glasgow on that occasion, stated that in the year 1840 the Corporation had realised the great importance of the teaching of geology to those employed in the development of mineral wealth. He was glad to be able to say that in the city museums at Kelvingrove they had been able to preserve the important collections of former members of the Geological Society. The city was to be congratulated on having had in its midst for fifty years such a body of voluntary workers as was represented by the Geological Society, and he thought the members might confidently look forward to even greater success than they had achieved.

Sir Donald MacAlister having acknowledged the vote of thanks on behalf of the University, the formal proceedings ended.

Short lectures were afterwards delivered in classrooms of the University by Dr. J. J. H. Teall on "The Foliation of Some Igneous Rocks," by Dr. J. Horne on "Recent Discoveries as to the Extension of the Campbeltown Coal Field," while Dr. B. N. Peach gave a demonstration in the museum of the geological department on the model of part of the North-West Highlands of Scotland.

A number of the delegates attending the Jubilee celebration of the Glasgow Geological Society were entertained to luncheon by the Corporation in the City Chambers. The Lord Provost occupied the chair, and the senior magistrate, Bailie Shaw Maxwell, acted as croupier. Among those present were Sir Archibald Geikie, K.C.B., P.R.S.; Professor Boyd Dawkins, Victoria University, Manchester; Dr. J. J. H. Teall, London; Dr. Traquair, Edinburgh; Dr. Horne, Edinburgh; Dr. Peach, Edinburgh; Principal Sir Donald MacAlister, K.C.B.; Professor Gregory, Professor Graham Kerr, the Magistrates, the City Treasurer, the Lord Dean of Guild, the Deacon-Convener, and the Preceptor of Hutchesons' Hospital. At the conclusion of the luncheon, and after the loyal toasts,

Digitized by Google

the Lord Provost gave the toast of "The Glasgow Geological Society," with congratulations on attaining its Jubilee. He cordially welcomed the delegates. The toast was coupled with the names of Sir Archibald Geikie, one of the original members, and Professor Gregory, the present President of the Glasgow Society.

Sir Archibald Geikie thanked most heartily the Corporation on behalf of the Society. Professor Gregory expressed the thanks of the Society to the Lord Provost for his hospitality to the delegates. The Society appreciated the invitation to the delegates, as the recognition of the Society by the city and by the delegates who had come from so far afield would be a most helpful stimulus to the future work of the Society. Bailie Shaw Maxwell proposed the toast of "The University of Glasgow," to which Sir Donald MacAlister replied. Bailie Dunlop proposed the toast of "Kindred Societies," coupled with the name of Dr. Teall, Director-General of His Majesty's Geological Survey, London, who replied. Professor Boyd Dawkins proposed "The Provost and Corporation of Glasgow." The Senior Magistrate replied.

Digitized by Google

PROCEEDINGS OF THE GEOLOGICAL SOCIETY OF GLASGOW.

SESSION 1908-1909.

REPORT OF THE COUNCIL.

According to custom the Council beg to submit to the members a report on the work and progress of the Society during the past twelve months.

The Membership has remained much the same as in former years, the yearly withdrawal being just about balanced by the accession of new members. The associate membership still continues to be recruited from year to year by an increasing number of students anxious to take advantage of the benefits afforded by the Society.

The Financial State of the Society will be reported upon by the Hon. Treasurer, and it will be found that he is able to report, upon the whole, favourably of the present position of the Society in that respect.

The Meetings of the fiftieth session, 8 in number, were taken part in by fully the regular average number of members, about 40.

The Papers and Specimens submitted at the various meetings were of great importance and interest. Among these may be mentioned Prof. Gregory on the Great Scandinavian Overthrust, and on Lord Kelvin's Contribution to Geology; Mr. Dron on Iron and Copper Mining in Shetland; Mr. Mort, The Passage of a Dolerite into a Hornblende Schist; Mr. Stark, Notes on the Geology of South East Arran; Mr. Tyrrell, Petrographical Note on a Dyke crowded with Rock Fragments near Barrhead; Mr. Boyle, The Occurrence of Ultrabasic Rocks in the Igneous Intrusions of Lugar, Cumnock District; Mr. Smith, The Discovery of Upper Coal Measure Fossils in Ayrshire; Mr. Macnair, Notes on an Ocellar Dolerite from Craigie Hill, Ayrshire; Messrs. Martin and Tyrrell on a Puddle Trench near Bannockburn, with Notes on the Geology of the Surrounding District; Mr. Reoch, Notes on the Shore Section at Brodick and Corrygills, Arran.

The Excursions during the summer were in most cases largely attended.

1. Kelvingrove Museum. Mr. Macnair.
2. Calderwood Glen. Mr. Macintyre.
3. Brodick, Arran. Mr. Reoch.
4. Motherwell. Mr. Dron.
5. Strathaven. Mr. Dunlop.

Digitized by Google

6. Glen Ogle and Glen Beich, Perthshire. Mr. Macnair.
7. Boylestone Quarry, Barrhead. Mr. Smith.
8. Lennoxtown and Craigen Glen. Mr. Anderson.
9. Garscube Estate. Mr. Renwick.
10. Lang Craigs, Dumbarton.
11. Giffnock Quarries. Mr. Tyrrell.
12. Carstairs. Prof. Gregory.
13. Lugar Water, Cumnock, and Cubb's Glen, Lugar. Mr. Boyle.
14. Ballagan. Mr. Somerville.
15. Finnich and Dhu Alt Glens. Mr. Sinclair.
16. Kilsyth and Denny. Prof. Gregory.

Mr. SINCLAIR will report to you upon the Library. He has spent much time during the past session in getting the books into order, and now that there is an immediate prospect of our getting more space for the housing of the books, it is hoped that the Library will soon be placed in perfect working order, and that a new edition of the Catalogue will be issued shortly.

Part 1, vol. xiii. of the *Transactions* was issued to the members early in the session.

On the 17th December, 1907, the Society lost by death its most distinguished member—the late Lord Kelvin—who had been President of the Society for twenty-one years. Dr. Gregory has given a detailed account of Lord Kelvin's geological work, which is published in the *Transactions* for the last session. A biographical notice of Lord Kelvin will also appear in the Jubilee Memorial volume, and his portrait will form the frontispiece to the same book.

The Society had also to mourn the death during the past session of Mr. David Murray, M.A., B.Sc., Rector of the Kilmarnock Academy. He joined the Society in 1898. Though he did not appear at many of the meetings yet he took an active interest in the Society's work. Mr. Murray also did a great deal of work in arranging and classifying the geological collections in the Kilmarnock Museum.

Another removal from the ranks of the Society was made by the death of Mr. Andrew Brown, North Mount Vernon. He was elected a member of the Society in 1887.

It will be remembered that last November Mr. Charles Cowie generously presented to the Society a cheque for £100. He suggested that the income should be used to pay the fees of students attending geological classes in Glasgow, but left the Council a free hand in that matter. It has now been resolved to apply it for the purpose intimated by Mr. Cowie.

In connection with the Baxter Demonstratorship in Geology, the University has agreed that the Demonstrator should give a number of lectures or demonstrations to the Society, and that this should in future form part of his duties. The first of these will be given to the Society during the present session.

Digitized by Google

During the past session the Committee charged with the arrangements for the Jubilee Celebrations have had a number of meetings, and they have now been practically completed. The Jubilee Celebrations will be held in the University on the evening of the 29th January.

SOCIETY'S ROOMS, 207 BATH STREET, 8TH OCTOBER, 1908.

The first meeting of the fifty-first Session of the Geological Society of Glasgow was held last evening—Mr. JOSEPH SOMMERVILLE, *Vice-President*, in the chair.

The Minutes of the previous meeting were read and adopted.

Professor J. W. GREGORY, D.Sc., F.R.S., read a paper on the geology of the Rand goldfield, in which he showed that the auriferous conglomerates are arranged in a syncline or trough, and that they rest upon an older series of schists that have been penetrated by granitic intrusions. Proceeding to discuss the probable origin of the gold in these deposits, the various theories that had been advanced were briefly passed in review. The author favoured the view which considered these deposits to be of alluvial origin, and discussed in detail a series of microscopic sections of the "banket beds" in which the gold occurs. These he showed had been subjected to considerable pressure, which had resulted in the development of secondary minerals, and tended to obscure the original fragmental character of the gold.

Mr. JAMES NEILSON read a paper entitled, "Review of Fifty Years' Work in Carboniferous Palæontology." After giving an account of the more important papers that had been contributed to the Society's *Transactions* on the palæontology of the Carboniferous rocks, the author gave a digest of the principal results that had been arrived at, and discussed in detail the different fossiliferous horizons that exist in the Carboniferous rocks of the West of Scotland, and the physical conditions of deposition which they indicate. In the concluding section of his paper, Mr. Neilson dealt with the zoning of the Carboniferous rocks, indicating the various horizons that he thought were characterised by specific forms.

(Signed) R. W. DRON, *V.P.*

SOCIETY'S ROOMS, 207 BATH STREET, 12TH NOVEMBER, 1908.

The second meeting of the fifty-first Session of the Geological Society of Glasgow was held here this evening—Mr. R. W. DRON, *V.P.*, in the chair.

At the outset the Chairman referred to the loss sustained by the Society in the death of Mr. Matthew Blair. A short biographical

Digitized by Google

notice by Mr. STARK was read. Mr. SOMMERVILLE moved that an expression of sympathy be sent to Mrs. BLAIR, and the fact recorded in the minutes. Mr. COWIE, in seconding, spoke of the delight that every one of Mr. BLAIR'S friends felt in his society.

The Minutes of the previous meeting were read and adopted.

The Council's Report, the Treasurer's Report, and the Report of the Librarian were then read and adopted.

The following office-bearers were elected:—

President—Prof. John Walter Gregory, D.Sc., F.R.S., proposed by Mr. Peter Macnair, Mr. Robert Dunlop, Mr. Joseph Sommerville, and Mr. John Renwick.

Vice-President—Mr. James Neilson, Milnbank, proposed by Mr. James Stark and Mr. Robert Dunlop.

Members of Council—Mr. John Renwick, proposed by Mr. James Stark, Mr. Robert Dunlop, Mr. Joseph Sommerville, and Mr William Sinclair; Mr. John M'Kellar, proposed by Mr. Joseph Sommerville and Mr. William Sinclair; Mr. James Stark, proposed by Mr. Joseph Sommerville, Mr. John Renwick, Mr. James Neilson, and Mr. Robert Dunlop; Mr. Robert Dron, proposed by Mr. Joseph Sommerville, Mr. John Renwick, Mr. James Neilson, and Mr. Robert Dunlop.

Hon. Secretaries—Mr. Peter Macnair, F.G.S., and Mr. Fred Mort, F.G.S., proposed by Mr. Joseph Sommerville and Mr. John Renwick.

Hon. Treasurer—Mr. E. H. Wight, proposed by Mr. Joseph Sommerville and Mr. John Renwick.

Hon. Librarian—Mr. William Sinclair, proposed by Mr. Joseph Sommerville and Mr. John Renwick.

ELECTION OF MEMBERS.

As Ordinary Members—Mr. David P. M'Donald, M.A., B.Sc., 11 Neilston Road, Paisley, proposed by Prof. J. W. Gregory and Mr. G. W. Tyrrell; Mr. Matthew M. Monie, c/o Hannan, 8 Smith Street, Hillhead, proposed by Mr. P. Macnair and Mr. F. Mort; Mr. Robert Boyle, B.Sc., 85 Preston Street, proposed by Mr. F. Mort and Mr. P. Macnair; Mr. George Hunter, M.I.M.E., Mining Department, Technical College, Glasgow, proposed by Mr. P. Macnair and Mr. F. Mort; Mr. R. S. Sharp, 275 Nithsdale Road, Dumbreck, Glasgow, proposed by Mr. J. Sommerville and Mr. F. Mort.

As Associate Members—Mr. A. Elliot, 87 Holmlea Road, Langside, proposed by Mr. P. Macnair and Mr. F. Mort; Mr. George D. Anderson, 2 Craignethan Gardens, Partick, proposed by Mr. P. Macnair and Mr. F. Mort; Mr. G. A. Hardy, 4 Windsor Terrace, St. George's Road, proposed by Mr. P. Macnair and Mr. F. Mort; Mr. William Miller MacLintock, 44 Thornwood Avenue, Partick, W., proposed by Mr. P. Macnair and Mr. F. Mort.

Mr. SOMMERVILLE, Mr. NEILSON, and Mr. COWIE thanked the retiring office-bearers for their services.

Digitized by Google

Mr. PEARSON and Mr. YOUNG were appointed auditors.

Mr. MACNAIR gave an account of the arrangements made so far by the Jubilee Committee for the celebration of the completion of fifty years' successful work by the society.

Mr. JAMES NEILSON exhibited fluorite, calcite, gypsum, and a petrifaction from Derbyshire, and made some interesting remarks on the geology of Derbyshire and the formation of these minerals.

Mr. PETER MACNAIR, F.R.S.E., F.G.S., exhibited some fine specimens of calcite and fluorspar from the collections at Kelvingrove Museum. The crystalline form and the methods of twinning were explained in each case.

Mr. G. W. TYRRELL, A.R.C.Sc., read a paper entitled "A New Occurrence of Picrite in the Ballantrae district and its Associated Rocks." [See *Transactions*, vol. xiii., p. 284.]

Mr. JAMES NEILSON then gave a description of the Scottish Carboniferous brachiopoda, by the aid of lantern slides supplied by Mr. J. W. Reoch and Mr. Wm. Sinclair. Special mention was made of Dr. Davidson's descriptions and illustrations of these forms, and the speaker stated that the student who knew Davidson's plates could identify nine out of every ten fossils he would meet in local Carboniferous rocks. Mr. NEILSON made remarks on the different structures exhibited by the fossils, and showed what part they played in the life history of the animal.

(Signed) J. W. GREGORY.

10th December, 1908.

SOCIETY'S ROOMS, 207 BATH STREET, 10TH DECEMBER, 1908.

The third meeting of the fifty-first Session of the Geological Society of Glasgow was held here this evening—Professor J. W. GREGORY in the chair.

The Minutes of the previous meeting were read and adopted.

Sympathetic reference was made to the death of Dr. JOHN DOUGALL, who was for many years a member of this Society, and who contributed to our *Transactions* an important paper on the geology of Cartland Crags, near Lanark.

The following members were elected:—

As Ordinary Members—Mr. Andrew C. Kerr, 125 Buchanan Street, Glasgow, proposed by Mr. P. Macnair and Mr. F. Mort; Mr. David Hendry, Dunmore, Johnstone, proposed by Mr. P. Macnair and Mr. F. Mort; Mr. Donald Mackay, c/o Downie, Aiton & Co., 190 West George Street, proposed by Mr. P. Macnair and Mr. F. Mort; Mr. C. D. Moir, 150 Hope Street, Glasgow, proposed by Mr. E. Hall Wight and Mr. F. Mort.

The following members were proposed:—

As Honorary Members—Mr. John Smith, Dykes, Dalry, proposed

Digitized by Google

by Mr. Joseph Sommerville and Professor J. W. Gregory; Professor Eduard Suess, Vienna, Austria, proposed by Professor Gregory and Mr. Joseph Sommerville; Dr. Wheelton Hind, B.Sc., F.G.S., Roxeth House, Stoke-upon-Trent, proposed by Mr. James Neilson and Mr. Robert Dunlop; Dr. J. J. Harris Teall, F.R.S., Director-General of the Geological Survey of Great Britain, Museum of Practical Geology, Jermyn Street, London, proposed by Mr. Joseph Sommerville and Professor Gregory.

As Corresponding Member—Mr. James Young, Lesmahagow, proposed by Mr. James Neilson and Mr. Robert Dunlop.

Mr. PETER MACNAIR, F.R.S.E., F.G.S., read a paper entitled "Notes on the Geology and Palæontology of Kelvingrove Park."

Mr. G. W. TYRRELL, A.R.C.Sc., read a paper entitled "The Geology and Petrology of the Igneous Intrusions of the Kilsyth-Croy District." The general geological structure of the district was first described. The intrusions appear as three masses, the two larger of which are separated by the alluvial deposits of the Kelvin Valley. They may be described as laccolites, although the lower surfaces cut across the bedding planes of the sedimentary rocks. These intrusions are closely connected with the system of east and west dykes of the district. In fact, in the speaker's opinion, some of these dykes were feeders that supplied the material to the main intrusions. Petrographically these rocks are of great interest. They present several marked differences from the usual doleritic types. They are characterised by frequently containing micropegmatite and hypersthene, and they show also some peculiarities in structure. Finally an account was given of the distribution of these rocks in this country and abroad, and of various theoretical speculations advanced recently regarding them.

Owing to the lateness of the hour, the discussion on Mr. Tyrrell's paper was postponed to the next meeting.

(Signed) J. W. GREGORY.

14th January, 1909.

SOCIETY'S ROOMS, 207 BATH STREET, 14TH JANUARY, 1909.

The fourth meeting of the fifty-first Session of the Geological Society of Glasgow was held here this evening—Professor GREGORY, F.R.S., in the chair.

The Minutes of the previous meeting were read and adopted.

The following members were elected:—

As Honorary Members—Mr. John Smith, Dykes, Dalry, proposed by Mr. Joseph Sommerville and Professor J. W. Gregory; Professor Eduard Suess, Vienna, Austria, proposed by Professor Gregory and Mr. Joseph Sommerville; Dr. Wheelton Hind, B.Sc., F.G.S., Roxeth House, Stoke-upon-Trent, proposed by Mr. James Neilson and Mr.

Digitized by Google

Robert Dunlop; Dr. J. J. Harris Teall, F.R.S., Director-General of the Geological Survey of Great Britain, Museum of Practical Geology, Jermyn Street, London, proposed by Mr. Joseph Sommerville and Professor Gregory.

As Corresponding Member—Mr. James Young, Lesmahagow, proposed by Mr. James Neilson and Mr. Robert Dunlop.

As Ordinary Members—Mr. C. D. Moir, 150 Hope Street, Glasgow, proposed by Mr. E. Hall Wight and Mr. Fred Mort; Mr. David Kerr, Lynnewood, 140 Bo'ness Road, Grangemouth, proposed by Mr. Peter Macnair and Mr. Fred Mort; Mr. James Knight, M.A., D.Sc., F.R.S.E., F.G.S., F.C.S., proposed by Mr. John Renwick and Mr. William Sinclair.

Mr. Jas. Stark exhibited a nodule containing shells dredged from the Clyde near Cardross. The speaker stated that the nodule had been lifted by a suction dredger. He then gave an account of how such concretions might be formed in different deposits both contemporaneously and by subsequent action.

Remarks were made by Professor Gregory, Mr. Dron, Mr. Macnair, and Mr. Gemmell.

A discussion was initiated on Mr. Tyrrell's paper on the Kilsyth-Croy district, read at the December meeting.

Professor Gregory discussed the references that had been made in the paper to the Atlantic and Pacific types of coasts. He stated that a new distinction had recently been added to the original contrasts put forward by Suess. This was a petrographic difference in the types. Fractures of the Atlantic type were supposed to cut into deep strata of considerable petrographic unity. This difference in the principles of classification sometimes led to the same coasts being assigned to different categories, as had happened with South Victoria Land.

Mr. Dron commented on the great economic importance of the paper, and stated that if such investigations could only be continued right across Scotland, mining engineers would be saved considerable sums.

Mr. F. Mort congratulated the author on the excellence of his paper, and discussed the principles of nomenclature of the rocks known as diabases and dolerites.

Mr. Macnair described some of his own investigations into rocks such as Mr. Tyrrell had described, particularly with reference to the hornblende and ilmenite contained in the rocks. He also discussed the E. and W. dykes of the region.

Mr. Anderson stated that he had long ago concluded that the lacolites of Kilsyth were connected with the E. and W. dykes.

Mr. Tyrrell replied to all the questions that had been asked and all the criticisms that had been made.

Professor Gregory, D.Sc., F.R.S., then read a paper entitled "Sideroplesite in the Glenboig Fireclays." The speaker gave a general description of the usual type of fireclays, and stated that these were

Digitized by Google

usually believed to have been the subsoil of Carboniferous forests. At Glenboig, however, there seems to be no evidence for this, as no roots can be found. The clay contains tiny rutile needles and grains of quartz and felspar. The felspar is usually fresh, which also militates against the belief that the clay was a soil. The bedding is also seen at times quite distinctly, especially in micro-section. In addition, minute crystals are seen of a rhomboidal habit, built up in zones with a radial structure. These are composed of carbonate of iron, with carbonite of magnesium, and have been determined to be sideroplesite. The speaker concluded that the fireclay had probably been formed under water, and that the absence of marine forms indicated lagoon conditions.

(Signed) J. W. GREGORY.

11th February, 1909.

SOCIETY'S ROOMS, 207 BATH STREET, 11TH FEBRUARY, 1909.

The fifth meeting of the fifty-first Session of the Geological Society of Glasgow was held in the rooms, Bath Street, this evening—Professor J. W. GREGORY, D.Sc., F.R.S., in the chair.

The Minutes of the previous meeting were read and adopted.

Mr. J. W. REOCH exhibited lantern slides from photographs taken at the excursion of the Society last summer. The series included many views of great geological interest, particularly fine being a large number of scenes in the heart of the granite mountains of Arran.

Mr. PETER MACNAIR, F.R.S.E., F.G.S., Hon. Secretary, read a paper entitled "Eyed Coal from Cambuslang." [See *Transactions*, vol. xiii., p. 291.]

(Signed) J. W. GREGORY.

11th March, 1909.

SOCIETY'S ROOMS, 207 BATH STREET, 11TH MARCH, 1909.

The sixth meeting of the fifty-first Session of the Geological Society of Glasgow was held here this evening—Professor J. W. GREGORY, D.Sc., F.R.S., in the chair.

The Minutes of the previous meeting were read and adopted.

The following members were elected:—

Mr. Matthew B. Gilmour, Saffron Hall House, Hamilton, proposed by Messrs. M'Intyre and Mort; Mr. Thos. Wise, Ailsa Cottage, Scott Street, Hamilton, proposed by Messrs. M'Intyre and Mort; Mr. G. M'Leod Tervet, Maybank, Gateside, Barrhead, proposed by Messrs. Wight and Macnair.

Digitized by Google

Mr. SOMMERVILLE gave notice that at next meeting he would move that £100 of the Life Members' Fund be used in paying the expenses of the publication of the History of the Glasgow Geological Society.

Mr. R. DUNLOP exhibited specimens of oil shales from New Zealand and Australia. He gave an account of the amounts of oil and wax contained in the different specimens. One series of specimens contained a large quantity of occluded sulphuretted hydrogen, which is given off on heating to the boiling point of water. Mr. Dunlop also exhibited specimens of "eyed" shale from Airdrie, and described the way in which he thought the structure had arisen.

Mr. G. W. TYRRELL, A.R.C.Sc., then read a paper entitled "The Classification of the Post-Carboniferous Intrusive Igneous Rocks of the West of Scotland." [See *Transactions*, vol. xiii., p. 298.]

(Signed) JOSEPH SOMMERVILLE.

5th April, 1909.

SOCIETY'S ROOMS, 207 BATH STREET, 5TH APRIL, 1909.

The seventh meeting of the fifty-first Session of the Geological Society of Glasgow was held here this evening—Mr. JOSEPH SOMMERVILLE, *Vice-President*, in the chair.

The Minutes of the previous meeting were read and adopted.

Mr. PETER MACNAIR, F.R.S.E., F.G.S., exhibited, on behalf of Professor D. Burns, M.I.M.E., a specimen of Productus from the Carboniferous limestone of Cumberland which had been replaced by haematite. Mr. DUNCAN SMITH exhibited a collection of shells from the post-glacial deposits of Seedhill Clayfield, Paisley, and gave a detailed account of the stratigraphy of the deposits and the physical conditions under which they had been accumulated.

Mr. DAVID P. MACDONALD, M.A., B.Sc., Baxter Demonstrator in Geology in the Glasgow University, read a paper entitled "Isomorphism: its Relation to the Chemical Composition and Physical Characters of Crystals." [See *Transactions*, vol. xiii., p. 318.]

(Signed) JOHN RENWICK.

GEOLOGICAL LABORATORY, GLASGOW UNIVERSITY, 29TH APRIL, 1909.

A special meeting of the Geological Society of Glasgow was held here this evening—Mr. JOSEPH SOMMERVILLE in the chair.

Mr. DAVID P. MACDONALD, M.A., B.Sc., gave a demonstration of the optical characters of minerals. At the outset he gave a brief sketch of the principal phenomena connected with the passage of light through

Digitized by Google

crystals. It was pointed out that minerals could be divided into two great classes—isotropic and anisotropic, or singly and doubly refracting substances. The doubly refracting crystals could again be sub-divided into those which possess one and those which possess two optic axes, these being respectively known as uniaxial and biaxial crystals. Mr. Macdonald then explained the manner in which the interference figures of such crystals could be observed in convergent light under the polarising microscope. A large series of minerals, specially prepared to show the optical characters of minerals, was exhibited under the microscope.

(Signed) JOHN RENWICK.

SOCIETY'S ROOMS, 207 BATH STREET, 13TH MAY, 1909.

The eighth meeting of the fifty-first Session of the Geological Society of Glasgow was held here this evening—Mr. JOHN RENWICK, *V.P.*, in the chair.

The Minutes of the previous meeting were read and adopted.

Mr. JOSEPH SOMMERVILLE moved the following motion (of which notice was given at the meeting of the 11th March):—

"That a sum not exceeding £100 be taken from the Life Members' Subscription Account and applied towards the expense of the publication of the Jubilee Volume."

Mr. M'INTYRE seconded.

Mr. WM. JOLLY protested against taking this serious step, and maintained that the money could be raised without encroaching on Life Members' funds. He moved the following amendment:—

"That a committee be appointed to consider the question, and, if necessary, to raise the required funds without drawing on life-membership subscriptions."

There was no seconder. Mr. Sommerville's motion therefore became the finding of the meeting.

The following members were elected:—

As Ordinary Members—James Williamson, A.M.I.C.E., 160 Hope Street, proposed by Mr. Patrick Arthur Leitch and Mr. P. Macnair; Mr. Gavin S. Alston, 20 Easwald Bank, Kilbarchan, proposed by Mr. J. Sommerville and Mr. P. Macnair.

As Associate Members—Miss Edith Bertha Hill, 13 Osborne Place, Ibrox, proposed by Mr. P. Macnair and Mr. F. Mort; Miss Jessie A. Houston, 83 Kilmarnock Road, proposed by Mr. P. Macnair and Mr. F. Mort.

Mr. JAMES W. REOCH exhibited specimens of Avicula contorta from Arran. The fossils came from the volcanic neck of Tertiary age, recently discovered in Arran, and are of Rhaetic age. Mr. Reoch also exhibited specimens of amethystine quartz from Glen Dubh, Arran,

Digitized by Google

and stated how they had probably originated. Mr. JAMES NEILSON exhibited Myalina redesdalensis, Nautilus tuberculatus, Meekella cylindrica, and Meekella senilis. The first named, from the Waulkmill Glen, is a species new to Scotland, and one specimen reaches 4½ inches in length. Mr. Neilson also gave an account of the light that these and other fossils threw on the conditions that obtained when the deposits were being formed. Mr. G. W. TYRRELL, A.R.C.Sc., and Mr. N. MARTIN, B.Sc., A.G.T.C., read a paper entitled "The Geology and Petrology of the Auchineden District, Kilpatrick Hills, with special reference to new sections exposed in the Clydebank Waterworks at Burn Crooks." [See *Transactions*, vol. xiii., pp. 322 and 337.]

(Signed) JOHN RENWICK.

SOCIETY'S ROOMS, 207 BATH STREET, 27TH MAY, 1909.

The ninth meeting of the fifty-first Session of the Geological Society of Glasgow was held here this evening—Mr. JOHN RENWICK, *V.P.*, in the chair.

The Minutes of the previous meeting were read and adopted.

The following members were elected:—

As Ordinary Member—Rev. A. Scott Mathieson, 7 Lynedoch Crescent, Glasgow, proposed by Mr. James Neilson and Mr. Peter Macnair.

As Associate Member—Mr. J. Wilson Massie.

Mr. ROBERT BOYLE, B.Sc., A.G.T.C., read a paper entitled "The Economic and Petrographical Geology of the New Red Sandstones of the South of Scotland, with their Associated Breccias." [See *Transactions*, vol. xiii., p. 344.]

EXCURSIONS FOR SEASON 1909.

To Kelvingrove Museum, on Saturday, 13th March—Mr. Peter Macnair, F.R.S.E., F.G.S., conductor. The party met in the Geological Gallery at 3 p.m. They then examined the recent additions to the geological collection, including the Melven Collection of Old Red Sandstone and Secondary Fossils from the North of Scotland.

To the Hunterian Museum, on Saturday, 27th March—Prof. J. W. Gregory, D.Sc., F.R.S., conductor. The party met at the Hunterian Museum, Glasgow University, at 3 p.m.

To Brodick, Arran, on Monday, 12th April (Spring Holiday)—Mr. James W. Reoch, conductor. The object of the excursion was to examine part of the Tertiary Volcanic Vent occurring in the centre of the island. The party proceeded by Invercloy, viewing the Lower Triassic rocks exposed on the shore, and thence to Brodick School, where a sill of pitchstone was examined. Proceeding by the String

Digitized by Google

Road, the vertical beds of Old Red Sandstone were traversed southward to the Carboniferous formation, and the outcrop of the Carboniferous Limestone followed, leading on to the intrusive quartz-porphyry of Windmill Hill summit. Thence the party proceeded around the head of Glen Ormidale, skirting the eastern edge of the vent, where the intrusions of granite, granophyre, quartz-diorite and diorite were examined, descending into Glen Dubh, where very fine examples of moraines occur; and returning down Glen Cloy to Brodick.

To Corrieburn, Stirlingshire, on Saturday, 24th April—Mr. James Anderson, conductor. The chief attraction is the extensive lime workings, where the Hurlet and Campsie series were largely worked in former times. The series were here found very fully developed, and also associated with valuable bands of limestone and ironstone, which have not been noted in any other locality. Overlying the lime series is a singularly fine exposure of brown shale, with regular bands of nodular ironstone concretions. The relationships of the sedimentary series to the volcanic deposits of the range are also to be studied under favourable conditions.

To Ardrossan and Saltcoats, Ayrshire, on Saturday, 1st May—Mr. John Smith, conductor. Part of the Lower Ironstone series and trap with sandstone dykes on the shore at Ardrossan were examined. Passing over the sands to Saltcoats, a part of the Upper Limestone series was seen, and between it and the Coal Measures there are volcanic ashes with a bed of ironstone. The lower part of the Lower Coal Measures has been invaded by sills which have charred some coal beds, and the strata present interesting features of contact metamorphism.

To Tyndrum, Perthshire, on Thursday, 20th May (Victoria Day)—Mr. Peter Macnair, F.R.S.E., F.G.S., conductor. After arriving at Tyndrum, the party examined the section exposed in the Allt nan Sae, which shows the Ben Lawers Phyllites faulted against a series of quartzites. Crossing the sides of Meall Odhar, the old workings of the Tyndrum Lead Mines were then examined. Specimens of Galena, Zinc-blende, Quartz, Pyrites, and other minerals occur here. On the walk between Tyndrum and Crianlarich the outcrops of the Garnetiferous Schists, Loch Tay Limestone, and associated epidiorites were examined.

To Duncomb, Kilpatrick Hills, Dumbartonshire (joint excursion with the Natural History Society of Glasgow), on Saturday, 22nd May—Mr. L. Watt, conductor. To the north of Kilbowie the party passed over a line of very deep drift supposed to be a buried river channel, and proceeded by Faifley, to the south of which the Hurlet Limestone and Coal crop out. Half a mile north of Faifley the Carboniferous Limestone series, dipping gently southward, is faulted against the bedded lavas of Calciferous Sandstone age forming the Kilpatrick Hills. These were traversed up the course of the Loch Humphrey Burn (where in places they show glaciation from the north-west) to the reservoir at Greenside, and thence over the moor to Duncomb (1313 feet), the summit of which is a plug of intrusive felstone. Zeolites occur in cavities in the lavas. The view from Duncomb in clear weather is extensive and very fine.

To Burn Crooks Waterworks, Auchineden Hill, and the Whangie, Dumbartonshire, on Saturday, 29th May—Mr. N. Martin, A.G.T.C., and Mr. G. W. Tyrrell, A.R.C.Sc., conductors. Good sections have recently been opened in the Calciferous Sandstone lavas of Auchineden Hill. At Burn Crooks excavations are proceeding in a plug of olivine basalt which overspreads a partially concealed volcanic "neck." In Burn Crooks and its tributaries can be seen good

Digitized by Google

agglomerate and tuff, with Calciferous Sandstones, dykes, &c. The great landslip known as the Whangie was visited in the course of the excursion. Good sections in boulder-clay, thick peat, &c.

To Shettleston, Glasgow, on Wednesday, 2nd June—Mr. James L. Begg, conductor. The objects of the excursion were to examine (1) an exposed section of the Upper Coal Measures at Shettleston Station, (2) some igneous sills near the Canal, and (3) a carried trap boulder exposed in a burn near Barrachnie.

To Murroch and Auchenreoch Glens, Dumbartonshire, on Saturday, 12th June—Mr. David Chalmers, conductor. Lofty sections of the Ballagan group of shales and cement stones are exposed in the glens, with several intrusive dykes. Fine examples of stream erosion. Minerals—Fibrous Gypsum (pure white) and Celestite.

To Seedhills Clayfield, Paisley, on Wednesday, 16th June—Mr. Duncan Smith, conductor. The object of the excursion was to examine the Post-Tertiary Deposits occurring in the clayfield, consisting of surface soil, earthy clay, yellow stony clay, black clay with an abundance of shells, &c., and laminated sandy clay. The total depth of the cutting is about 28 feet, and, as the surface datum is about 30 feet above sea-level, the lowest part of the section is thus about coincident with the sea-level. Stones of various kinds—granite, grit, sandstone, limestone, porphyrite, basalt, &c.—are in greater or lesser evidence.

To Finnich and Dhu Alt Glens, Dumbartonshire, on Saturday, 26th June—Mr. William Sinclair, conductor. These very beautiful glens present fine examples of river erosion in the Red Sandstones, Calciferous Series. Finnich Glen is one of the finest cañons in the West—quite unique in its way—and shows river caldrons high up in the cliffs.

To Garngad, Glasgow, on Wednesday, 30th June—Mr. James Neilson, conductor. The quarries which are immediately to the east of Garngad Road Station, N.B. Railway, were visited. These have been opened in strata of Millstone Grit age, which here consist of sandstones—mostly soft—shales, cannel and free coal, coarse ironstone, and fireclay. The sandstones are crushed for use as moulders' sand, and the other strata used in the manufacture of bricks. The quarries show both thick and thin beds which are frequently faulted. In the adjoining railway cutting were found Roman Cement and marine shales, overlying which were found various sandstones containing marine fossils, these strata all underlying the quarries; while in the shales in the Garngad Road quarry were found various marine shells. The whole shows a transition state, in which the marine conditions were slowly passing away, to be replaced by the freshwater series characteristic of Upper Carboniferous times. The fossils also show a transition state. The American genera of shells, which have been found near Glenboig, should be looked for here, while the American genus "Meekella" has been identified from this locality. (See *Trans.*, vol. v., p. 222. At this time the southmost of the two quarries, viz., the Blochairn quarry, had been opened.)

To Mauchline, Ballochmyle, and Ayr Water, on Saturday, 3rd July—Mr. Robert Boyle, B.Sc., conductor. The objects of the excursion were (1) to visit the Ballochmyle quarries, worked to a depth of 200 feet at the eastern edge of the basin of Permian (?) brick-red sandstone; (2) to examine the igneous intrusion of later age at Howford bridge, and the ash interbedded in the sandstone; (3) to inspect the gorge of the Water of Ayr west of this. The depth at some parts is about 100 feet. There are excellent sections showing the amygdaloidal melaphyres and tuff at the base of the red sandstone, and also intercalated with it. The striking characteristic of the sandstone everywhere is its abundant false-bedding. The scenery is exquisite.

Digitized by Google

To Thornton Hall and Hairmyres, Lanarkshire, on Saturday, 7th August—Mr. James Neilson, conductor. The strata here consist of the upper members of the great volcanic series of Calciferous Sandstone age, which, during a period in which the land slowly sank, became first the shore and then the sea-bottom on which what are perhaps the earliest of our marine remains were laid down. The quarries visited, and which are still wrought, are fully described in two papers in the Society's *Transactions*, vol. iv.; p. 276, and vol. ix., p. 282. They contain limestone, marine shale, oil shale with fish remains, entomostracan shale, fireclay with Stigmarian roots, ironstone, and volcanic ash, and at various times have freely yielded fossils—many finely preserved—including remains which have been supposed to belong to reptiles (although this is doubtful), as well as fishes, both marine and freshwater, mollusca, entomostraca, and land plants.

To Fiddler Gill, Crossford and Tillietudlem, Lanarkshire, on Saturday, 21st August—Professor Daniel Burns, M.I.M.E., conductor. The main features to be observed are outcrops of Shelly and *Productus* Limestones, Terra Cotta clay-beds, *Productus punctatus* ironstone beds, outcrops of Main and Lingula Limestones, and good exposures of underlying fossiliferous shales, gas coal series. Fossils may be collected at most of the places.

To Innellan and Dunoon, Argyllshire, on Saturday, 11th September —Mr. Peter Macnair, F.R.S.E., F.G.S., conductor. The Highland boundary fault enters the Firth of Clyde near Innellan Pier. Along the shore to the south there is a fine exposure of the Upper Old Red Sandstone conglomerates, sandstones, and cornstones. Near the line of fault a band of serpentine occurs. To the north of the fault line, and between Innellan and Dunoon, the following schist zones are exposed:—The Innellan Phyllites, the Bull Rock Greywacke, and the Dunoon Phyllites. The schists exhibit many interesting structural features, due to dynamic metamorphism. Both the schists and sandstones are traversed by numerous volcanic dykes.

To Carronbridge, Dumfriesshire, on Monday, 27th September (Autumn Holiday)—Mr. John Smith, conductor. After leaving Carronbridge Station a bit of Permian strata was passed over. At the mouth of Dalveen Pass there are mounds of drift, and in the Pass accumulations of gravel are taking place. Going up the Carron Water Silurian rocks were seen, mostly on edge, with some conglomerates. Passing through the Mid Pot—a dry river channel—Enterkin Glen was reached. Skirting round the steep sides of the Steygail, and going down the Enterkin Burn, the party reached Glen Valentine, where Carboniferous strata rest on the upturned edges of the Silurian rocks. Near this there are some good exposures of melaphyres. The famous and beautiful "Durisdeer Marbles" were inspected during this excursion.

To Gryfe Valley, Bridge of Weir, Renfrewshire, on Saturday, 16th October—Professor J. W. Gregory, D.Sc., F.R.S., conductor. The object of the excursion was to examine the Lower Carboniferous Limestone series, including the Hosie and Hurlet Limestones, faulted down against the Calciferous volcanic series.

Digitized by Google

Erratum.—On page 273 "Report of the Council for 1904-1905" should read "Report of the Council for 1905-1906." Owing to this error the excursions in 1906 have been twice inserted, while the excursions in 1905 have been omitted. A list of the excursions in 1905 is therefore given below:—

EXCURSIONS FOR SEASON 1905.

The excursions during 1905 were as follows:—

To Kelvingrove Museum—25th February.
To cuttings near Kilbirnie on the new branch of the G. & S.-W. Railway from Johnstone to Dalry—11th March.
To Calton Hill, Edinburgh—18th March.
To Bathgate, Linlithgowshire—1st April.
To cuttings on new branch railway, Johnstone to Dalry, near Maich Water—15th April.
To Corrieburn, Stirlingshire—17th April.
To Sauchrie, Maybole, Ayrshire—24th April.
To Broxburn Oil Works, Linlithgowshire—29th April.
To Campsie Hills, Stirlingshire—13th May.
To Aberdour and Burntisland, Fifeshire—25th May.
From Manuel, Stirlingshire, to Bo'ness, Linlithgowshire—10th June.
To The Whangie, Stirlingshire—24th June.
To Largs, Ayrshire—12th August.
From Barrhead to Paisley, Renfrewshire—9th September.
To Arthur's Seat, Midlothian—7th October.

Evening Excursions.

To Hamilton Hill, Glasgow—18th May.
To Giffnock, Renfrewshire—18th June.
To Cathkin, Lanarkshire—29th June.

Digitized by Google

ABSTRACT OF THE TREASURER'S ACCOUNTS FOR THE YEAR ENDED 30TH SEPTEMBER, 1908.

CASH ACCOUNT.

RECEIPTS.			EXPENDITURE.		
To Cash in Bank on Deposit,	£94 0 0		By Transactions—		
,, Cash in Treasurer's hands,	4 6 11		Printing and Publishing Vol. XIII., Part 1, and for Reprints of Papers,	£47 14 4	
		£98 6 11	Postages, Typing, etc.,	1 13 3	
					£49 7 7
,, Subscriptions for current year (including 9 new Ordinary Members)—153 at 10/,		76 10 0	,, Library—New Books, Maps, and Magazines,		3 6 6
,, Do. (including 2 new Members), 3 at 7/6,		1 2 6	,, Subscription to Marine Biological Association, 1908,		1 1 0
,, Do. Arrears—1 at 10/,		0 10 0	,, ,, to Palæontographical Society, 1908,		1 1 0
,, Life Membership Subscriptions—1 at £5 5s.,		5 5 0	,, Rent, Insurance, and Attendance,		13 10 0
,, Associate Members' Subscriptions—14 at 2/6,		1 15 0	,, Printing and Postage of Circulars, Excursion Booklets, and Advertising,		17 7 4
,, Handbooks and Catalogues sold,		0 1 3	,, Lantern Expenses,		2 3 6
,, Interest on Funds,		9 2 2	,, Collector's Commission,		1 13 6
,, Mitchell Library for 40 Copies of *Transactions*,		8 8 6	,, Disbursements by Hon. Secretaries, Postages, Stationery, and Petty Expenses,		4 12 7
			,, Cash in Bank on Deposit,	£105 0 0	
			,, Cash in Treasurer's hands,	1 18 4	
					106 18 4
		£201 1 4			£201 1 4

STOCK ACCOUNT.

To Life Subscription Account,		£278 5 0	By Campbeltown Corporation Loan,	£270 0 0	
,, Capital Account,*		598 13 4	,, Cash in Bank and on hand,	106 18 4	
					£376 18 4
			,, Property—		
			Books in the Library,	£440 0 0	
			Furniture, Bookcases, and Microscope,	60 0 0	
					500 0 0
		£876 18 4			£876 18 4

* NOTE.—Subject to cost of publishing *Transactions*.

LIFE SUBSCRIPTION ACCOUNT.

Sept. 30, 1908—To Balance to Credit,	£278 5 0	October 1, 1907—By Balance,		£273 0 0
		Sept. 30, 1908—By Subscriptions during Year,		5 5 0
	£278 5 0			£278 5 0

Mr. CHARLES R. COWIE'S DONATION.

Sept. 30, 1908.—To Balance to Credit,	£101 14 9	Nov. 15, 1907.—By Cash,	£100 0 0
		Sept. 30, 1908.—Interest,	1 14 9
	£101 14 9		£101 14 9

GLASGOW, *9th October*, 1908.—Examined, compared with relative Vouchers and Securities, and found correct, the balance in Treasurer's hands being One Pound, Eighteen Shillings and Four Pence.

D. PEARSON,
JOHN RENWICK, } *Auditors.*

Digitized by Google

INDEX TO VOL. XIII.

1905-1909.

	PAGE
Abstract of Treasurer's Accounts for 1905, ...	113
Abstract of Treasurer's Accounts for 1906, ...	114
Abstract of Treasurer's Accounts for 1907, ...	281
Abstract of Treasurer's Accounts for 1908, ...	426
Address by Sir Archibald Geikie on Pioneers of Geology in the Glasgow District, ...	391
Age of the Earth, Lord Kelvin on, ...	173
Airdrie, Notes on Mineral Seams round. By Robert Dunlop, ...	35
Alethopteris valida, ...	269
Allorisma maxima, ...	103
Amethystine Quartz from Arran, ...	420
Anthrapalæmon, ...	99, 268
Arden Basin, Stratigraphy of. By R. G. Carruthers and E. M. Anderson, ...	133
Argyll's Bowling Green, ...	4
Arklestone Dolerite, ...	59
Arran, Notes on Shore Section at Brodick and Corrygills. By James W. Reoch, ...	255
Arran, South-east, Notes on Geology of. By James Stark, ...	191
Auchineden District, Kilpatrick Hills, Geology of. By G. W. Tyrrell and N. Martin, ...	322
Auchineden District, Kilpatrick Hills, Petrology of. By G. W. Tyrrell,...	337
Avicula contorta, ...	420
Ballantrae District, A new occurrence of Picrite in. By G. W. Tyrrell, ...	283
Basalt from Dunglass Hill, ...	102
Baxter Demonstratorship, ...	412
Ben Macdhui, ...	87
Blackhall Dolerite, ...	58
Blair, Matthew, Death of, ...	413
"Blue-ground" of Kimberley, ...	104
Bos longifrons, Bones of, encrusted with Vivianite, ...	269
Camp Siluria, Specimens from, ...	87
Carboniferous Fossils gathered near Dalry. By Wm. Jolly, ...	269

Digitized by Google

PAGE
Cladodus striatus 266
Classification of Post-Carboniferous Intrusive Igneous Rock of the West of Scotland. By G. W. Tyrrell, ... 298
Climate, Geological History of, Lord Kelvin on, ... 178
Clyde Valley, Relief Model of, ... 95
Constitution, Revised and Adopted, ... 92
Constitution, as Amended, Session 1905-1906, ... 118
Cowie, Charles R., Donation by, ... 265, 412
Crushing Tests of Sandstones, ... 380
Crystals of Calcite from Thorntonhall, ... 270
Ctenodonta pentonsis, ... 264

Dansken, John, Death of, ... 88, 90
Demonstration of some of the Optical Properties of Minerals. By David P. M'Donald, ... 321
Derbyshire Minerals, ... 415
Dolerites in the Neighbourhood of Glasgow, The Intrusive. By Peter Macnair, ... 56
Dolerite of Cathcart, ... 81
Dolerite of Necropolis Hill, ... 10, 79
Dolerite, The Passage of, into a Hornblende Schist. By Frederick Mort, ... 187
Dolerite showing Ocellar Structure from Craigie Hill, Notes on. By Peter Macnair, ... 235
Dolomite from Sunderland, ... 93
Dolomitic Limestone from Ortler Spitz, ... 98
Dyke crowded with Rock Fragments near Barrhead, Petrographical Notes on. By G. W. Tyrrell, ... 195
Dykes in the Valley of Loch Long. By James Stark, ... 162

Economic and Petrographic Geology of the New Red Sandstones of the South and West of Scotland. By Robert Boyle, ... 344
Edmondia pentonsis, ... 264
Eigg, Scuir of, ... 98
Excursions in 1905, ... 425
Excursious in 1906, ... 105
Excursions in 1907, ... 108
Excursions in 1908, ... 276
Excursions in 1909, ... 421
"Eyed" Coal from Gateside Colliery, Cambuslang, Notes on. By Peter Macnair, ... 291

Faröe Islands. By James Currie, ... 92
Fossil Grove Dolerite, ... 60
Fossils from Pollok Pit, ... 99
Fossils from Silurian Rocks, Girvan, ... 99
Fossils of Mineral Seams round Airdrie, ... 41

Digitized by Google

PAGE
Garngad Quarry, Specimens from, ... 101
Gasteropod Track from Chryston, ... 99
Geikie, Sir Archibald, Jubilee Celebration Address by, ... 391
Geology of Dunnet Head. By B. N. Peach, ... 96
Geology and Scenery of West Sutherland and Ross. By B. N. Peach, 104
Geology of the Auchineden District, Kilpatrick Hills. By G. W. Tyrrell, ... 322
Giffnock Sandstones, Notes on Irregular Bedding in. By Peter Macnair, ... 102
Glaciated Rock Surface at Lugton. By J. W. Gregory, ... 10
Glasgow's Highland Park, Notes on Geology of. By James Stark, 4
Glen Fruin Moraine, ... 46
Glyptoscorpius from the Coal Measures of Airdrie. By B. N. Peach, 1
Gold Mill (Native) from Rhodesia, ... 90
Goodchild, J. G., Notice of Life and Work of. By J. B. Murdoch, 94
Gyracanthus and Gyracanthides, Notes on. By James Neilson, ... 102
Gyracanthus Youngii, Traq., ... 99

Heads of Ayr, Specimens of Rocks from, ... 99
Highlands from Dumgoyn, ... 24
Highlands from Glasgow, ... 29
Highlands from Gourock, ... 26
Horne, J., on the Campbeltown Coal Field, ... 409

Ichthyocrinide, ... 264
Iona, A Holiday at. By E. W. Gemmell, ... 100
Iron and Copper Mining in Shetland. By R. W. Dron, ... 165
Isomorphism. By David P. M'Donald, ... 318

Jubilee Celebration, Special Meeting, ... 385

Kelvin, Lord, Death of, ... 268
Kelvin's (Lord) Chief Additions to Geological Literature, Classified List of, ... 180
Kelvin's (Lord) Contributions to Geology. By J. W. Gregory, ... 170
Kelvingrove Park, Notes on Geology and Palæontology of. By Peter Macnair, ... 416
Kilsyth-Croy District, Geology and Petrology of Igneous Intrusions of. By G. W. Tyrrell, ... 416, 417

Limestone containing Copper Carbonite and Iron Pyrites, ... 94
List of Members, October, 1907, ... 124
Loch Lomond Moraines, The. By John Renwick and J. W. Gregory, ... 45
Lugar and Cumnock District, Ultra-basic Rocks of, ... 202
Lugton, A Glaciated Rock Surface at. By J. W. Gregory, ... 10

Digitized by Google

PAGE
M'Lennan, J. S., Death of, ... 87, 90
Magnetite, Occurrence of, in Schists of Loch Long. By Peter Macnair, ... 98
Meekella cylindrica, ... 421
Meekella senilis, ... 421
Megalichthys hibberti (Ag.), ... 104
Members, List of, October, 1907, ... 124
Mineral Seams round Airdrie, Notes on. By Robert Dunlop, ... 35
Monazite, ... 93
Moraines, The Loch Lomond. By John Renwick and J. W. Gregory, ... 45
Mountains seen from Greenock, ... 27
Mountains seen from Ruchill, ... 31
Mountains seen from Springburn, ... 30
Murdoch, J. Barclay, Death of, ... 97
Murdoch, J. Barclay, Exhibition of Portrait of, ... 103
Murdoch, J. Barclay, Notice of. By Wm. Jolly, ... 105
Murdoch, J. Barclay, Resignation of, ... 89
Murray, David, of Kilmarnock, Death of, ... 267, 411
Musical Sand from Eigg, ... 97
Myalina redesdalensis, ... 419

Nautilus tuberculatus, ... 421
Necropolis Intrusion, Its Extension Westwards. By Frederick Mort, ... 19
New Red Sandstones of South and West of Scotland, Economic and Petrographic Geology of. By Robert Boyle, ... 344
Nodule containing Shells from Clyde at Cardross, ... 417
Notes on a Dolerite showing Ocellar Structure from Craigie Hill. By Peter Macnair, ... 235
Notes on an Ascent of Ben Macdhui. By James Neilson, ... 87
Notes on Distribution of Copper in Huelva District, Spain. By John Fingland, ... 95
Notes on Effects of Weathering on Scottish Metamorphic Rocks. By G. W. Tyrrell, ... 33
Notes on "Eyed" Coal from Gateside Colliery, Cambuslang. By Peter Macnair, ... 291
Notes on Geology of Mull and Neighbourhood. By James Neilson, 95
Notes on Geology of South-east Arran. By James Stark, ... 191
Notes on Mineral Seams round Airdrie. By Robert Dunlop, ... 35
Notes on Shore Section at Brodick and Corrygills, Arran. By James W. Reoch, ... 255

Objects of the Society, ... 116
Occurrence of Ultra-basic Rocks in Lugar and Cumnock District. By Robert Boyle, ... 202
Office-bearers, Session 1906-1907, ... 117

Digitized by Google

PAGE
Oil Shales from New Zealand, ... 419
Optical Properties of Minerals, Demonstration of. By David P. M'Donald, ... 321
Osmundites, ... 101
Osteolepis microlepidotus (Ag.), ... 90

Passage of a Dolerite into a Hornblende Schist. By Frederick Mort, ... 187
Peach, B. N. Demonstration on Model on North-West Highlands, 409
Perlitic Structure (Artificial) in Canada Balsam, ... 102
Petrographical Notes on a Dyke crowded with Rock Fragments near Barrhead. By G. W. Tyrrell, ... 195
Petrology of the Auchineden District, Kilpatrick Hills. By G. W. Tyrrell, ... 337
Picrite, A new occurrence of, in the Ballantrae District. By G. W. Tyrrell, ... 283
Photographs of Arran Granites, ... 266
Photographs of Giffnock Quarries, ... 101
Photographs taken at Excursion Localities, 1907, ... 268
Photographs taken at Excursion Localities, 1908, ... 418
Photo-micrographs by Lumière Colour Process, ... 264
Pioneers of Geology in the Glasgow District. By Sir Archibald Geikie, ... 390
Pitchstone from Eigg, ... 97
Proceedings for Session 1905-1906, ... 87
Proceedings for Session 1906-1907, ... 87
Proceedings for Session 1907-1908, ... 264
Proceedings for Session 1908-1909, ... 411
Productus replaced by Hæmatite, ... 419
Puddle Trench Section near Bannockburn, with notes on Geology of District. By N. Martin and G. W. Tyrrell, ... 240

Rand Goldfield, Geology of. By J. W. Gregory, ... 413
Report of the Council for Session 1903-1904, ... 270
Report of the Council for Session 1904-1905, ... 88
Report of the Council for Session 1905-1906, ... 273
Report of the Council for Session 1906-1907, ... 275
Report of the Council for Session 1907-1908, ... 411
Review of Fifty Years' Work in Carboniferous Palæontology. By James Neilson, ... 413
Rhizodus hibberti (Ag.), ... 99

Scandinavian Overthrust, The Great. By J. W. Gregory, ... 264
Scottish Carboniferous Brachiopoda. By James Neilson, ... 415
Shells from Post-Glacial Deposits of Seedhill Clayfield, Paisley. By Duncan Smith, ... 419
Sideroplesite in the Glenboig Fireclays. By J. W. Gregory, ... 417

Digitized by Google

PAGE

Southern Highlands from the Clyde Valley. By F. Mort and John Frew, ... 23
Sphærosiderite, ... 94
Spirifera, ... 90
Stalactite from Buxton, ... 93
Stratigraphy of the Arden Basin. By R. G. Carruthers and E. M. Anderson, ... 133
Stinkstein from Seefield Limestone, ... 97
Streblopteria lævigata, ... 266
Swiss Glaciers, Among the. By James Neilson, ... 267

Teall, J. J. H., on the Foliation of some Igneous Rocks 409
Tealliocaris, ... 268
Testimonial to J. Barclay Murdoch and John Wight, ... 94
Teruelite, ... 268
Testing of Sandstones, ... 369
Thorite, ... 93
Travertine, ... 97
Two Dry Channels near Dublin. By James Neilson, ... 104

Ultra-basic Rocks of the Lugar and Cumnock District. By Robert Boyle, ... 202
Upper Coal Measure Fossils in Ayrshire, Discovery of. By John Smith, ... 224

Vesuvius, The Story of, 63 A.D. to 1906. By John Main, ... 97

Weathering of Sandstones in Buildings, ... 373
Weathering on Scottish Metamorphic Rocks, Notes on. By G. W. Tyrrell, ... 33
Whangie, The, ... 329
Williamson, Captain, Death of, ... 96
Woodocrinus, ... 264

Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google

GRTON LIBRARY

Digitized by Google

The Ohio State University
3 2435 06558241 3

Digitized by Google